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MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. CXLVI.

1900/01

EDITED BY

J. H. T. TUDSBERY, D.Sc., M. INST. C.E., SECRETARY.

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CORRIGENDA.

Vol. cxlv. p. 246, line 3 from bottom, *for* $R + \left(\frac{G+d}{2}\right)$ *read* $R + \left(\frac{G-d}{2}\right)$.

,, ,, p. 254, ,, 2, *for* $\frac{(\cos\delta - \cos\alpha)}{(G-d)}$ *read* $\frac{(G-d)}{(\cos\delta - \cos\alpha)}$.

,, ,, p. 370, ,, 2 from bottom, *insert* "no" *before* "drifting."

,, ,, p. 384, lines 5 and 6 of middle abstract, *for* "the following various heat losses" *read* "the heat losses due to the following causes."

,, ,, p. 420. The title of the abstract should be "Power-Gas, and large Gas-engines for Central Stations. H. A. Humphrey."

,, ,, p. 434, line 17 from bottom, *for* "next" *read* "1901."

THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1900-1901.—PART IV.

SECT. I.—MINUTES OF PROCEEDINGS.

2 April, 1901.

JAMES MANSERGH, President, in the Chair.

It was announced that the Associate Members hereunder mentioned had been transferred to the class of

Members.

ERNEST FREDERICK DAWSON.
ERNEST RICHARD DOLBY.
FRANK GROVE.
GEORGE MOSS HARRIOTT, C.I.E.
RICHARD EUSTACE TICKELL.

And that the following Candidates had been admitted as

Students.

JAMES ALEXANDER.
RONALD CHRISTOPHER BAYNES.
COBBY GARLAND BEVAN.
ROBERT STANLEY BRAILSFORD.
ROBERT WELLESLEY ANTONY BREWER.
ALFRED WILLIAM BURFORD.
JOHN BUSFIELD.
EDWIN CHAPPELL.
COLIN CLARK.
GEORGE JAMES DAY.
CHARLES ERNEST GOAD, jun.
LAURENCE THORNEWAITE GRACE.
BENJAMIN WILLIAM PATON GREIG.
WALTER TOKE HALLWARD.
CHARLES EDWARD HANDY.
WILLIAM EDWARD HOGG.
ARNOLD HENRY HUMAN.
WILLIAM HENRY HUXHAM.
EDWARD JAMES KIRBY.
AUBREY RICHARD LANGTON.
WILLIAM LAWSON.
HENRY ANGLEY LEWIS-DALE.
JOHN EDWARD LISTER.
HAROLD BERTRAM MATHEW.
ERNEST CUMMING NIVEN.
CHARLES HENRY PAXTON.
FRANK ATKINSON PICKLES.
BERTRAM DARELL RICHARDS.
NILS PERCY PATRICK SANDBERG.
FRANCIS WILLIAM BERTRAM SCHOLEFIELD.
WILLIAM FREDERICK SMITH.
HERBERT EDWARD STEINBERG.
PHILIP HOWARD THORNE.
ARTHUR FRANCIS TREDCROFT.
WILLIAM ARTHUR WALES.
JAMES WATT.
EDWARD PARNELL WIDDICOMBE, B.A. (*Cantab.*)
JOSEPH LUPTON WILSON.
WILLIAM WELLESLEY WOOD.
JOSEPH BENTLEY ZAMBRA.

The Candidates balloted for and duly elected were: as

Members.

IRA GRANT HEDRICK.
JOHN SCOTT.

Associate Members.

JAMES HENRY BAILEY.
ROBERT FORBES BENNETT.
CHARLES HERBERT BISHOP.
ALFRED BROWN ERNEST BLACKBURN, Stud. Inst. C.E.
ARTHUR CAMERON.
ROBERT WILSON DRON.
SAMUEL EDGAR FEDDEN.
WILLIAM AINSLIE FOULIS.
GEORGE JOHN FREUND, jun.
HENRY DUDLEY GILL.
FREDERICK AUSTEN HADOW.
ROGER GASKELL HETHERINGTON, M.A. (*Cantab.*), Stud. Inst. C.E.
EDWARD HODGSON.
GEORGE ERNEST HOOPER, Stud. Inst. C.E.
JOHN INGLIS, B.Sc. (*Edin.*) Stud. Inst. C.E.
CECIL DAUBENY INMAN.
JOHN WILLIAM KITCHIN.
HARRIS JÜRGEN CARL KÜHL.
FREDERIC WINFRIED LA TROBE-BATEMAN.
FREDERICK CHARLES LEA.
DAVID ERNEST LLOYD-DAVIES, Stud. Inst. C.E.
ATHOL LOCKET.
JOHN MACLEAN.
ROBERT CREASY MASTER.
LEWIS MITCHELL.
HENRY LAWRENCE PEARSON, Stud. Inst. C.E.
WILLIAM HENRY PRESCOTT.
THOMAS WILLIAM RUSSELL.
FREDERIC BOLTON SONNENSCHEIN.
DAVID MCTAGGART SYMMERS, M.A. (*Aberdeen.*)
THOMAS GEORGE HOWES THOMAS.
GILBERT THOMSON, M.A. (*Edin.*)
HORATIO EDGAR DAWSON WALKER.
GERARD NORMAN WATNEY, B.A. (*Cantab.*)
THOMAS AUBREY WATSON.
ARTHUR HERRING WEIR.
EDWARD WILLIS.

An Associate.

ARTHUR GEORGE BLOXAM.

(*Paper No. 3265.*)

"The Burrator Works for the Water-Supply of Plymouth."

By EDWARD SANDEMAN, M. Inst. C.E.

THE waterworks of Plymouth date from the year 1590. In December of that year Sir Francis Drake, who appears to have been an engineer as well as a navigator, began to cut the open channel or watercourse from Dartmoor to Plymouth, now known as "the leat," which was destined to convey to Plymouth its supply of water during the succeeding 300 years. The leat, which was 18 miles 3 furlongs in length, appears, from the old records of the town, to have been made between December, 1590, and April, 1591. It was made in virtue of powers—conferred by an Act of Parliament of Queen Elizabeth's reign, dated 1585, —which authorised the Corporation of Plymouth to build a weir across the River Mewe, or Meavy, and to divert the water of that river into a trench which had a specified width of 6 feet or 7 feet

but no specified depth. The distance from the weir on the River Meavy to Plymouth in a straight line was not more than 10½ miles, but the winding course followed by the leat, contouring the hilly country through which it passes, accounts for its much greater length. When first brought into the town the water was distributed by means of open channels through the streets, which, at a later period, were superseded by lead pipes. Later still, on the introduction of iron pipes, the water was supplied under pressure from four small service-reservoirs constructed at different elevations. The last of these constructed was the Roborough reservoir, which is situated 6 miles north of the town, at an elevation of 547 feet (Fig. 1, Plate 1). On the completion of this reservoir in 1885 the use of the portion of the leat to the south of it was abandoned in favour of a line of pipes, the northern portion, about 8 miles long, remaining in use.

During the last 25 years the supply of water has frequently run short owing to drought, to leakage of water from the leat in summer, and to the effects of snow and frost in winter, and during this period many schemes for the storage of water and for the protection of the open leat have been proposed. In the year 1887 an Act of Parliament was obtained for the construction —at the foot of the gathering ground—of a reservoir having a capacity of 350 million gallons, to be called the Head Weir Reservoir, and land was bought for the purpose. This scheme was abandoned, however, owing to the discovery of a porous layer of decomposed granite, upwards of 100 feet thick, on the site of the proposed embankment. In 1889 plans were deposited for the construction of a reservoir to be called the Harter Reservoir, which was to be formed by a dam extending across the junction of two valleys, about 2 miles to the north of the first reservoir proposed. To this proposal many townspeople objected, and it was abandoned after a poll of the town had shown a majority against it. The Author, having been appointed Water Engineer to the Corporation in July, 1891, presented a report in December of that year, recommending the building of a storage-reservoir to be called the Burrator Reservoir, ¾ mile below the proposed Head Weir Reservoir, and the substitution of a line of pipes for the open leat. In 1892 this report was submitted to and approved by Mr. James Mansergh, President Inst. C.E., who also assisted in promoting the passage of the Bill through Parliament, and acted throughout as Consulting Engineer. The works were commenced on the 9th August, 1893, two months after the Royal Assent to the Bill was received.

General Description.

The watershed lies on the western slope of Dartmoor, at an elevation varying between 700 feet and 1,600 feet, its most northerly point being North Hessary Tor, which is close to Princetown and 13 miles in a north-easterly direction from Plymouth. By the new scheme the area of the watershed was increased from 4,885 acres to 5,360 acres. Almost the whole of this area lies on the granite formation, only a small portion on the west being on the upper Devonian. On the hills, locally called "tors," the rock lies close to the surface as a rule, but in many places the valleys are filled to a considerable depth with decomposed granite, in which are large boulders. The rainfall, as recorded by the existing gauges, which with one exception were fixed in 1892, is about 58 inches to 60 inches per annum. From the large dry-weather flow of the river it would appear that the quantity of water absorbed during wet weather is very large. Probably it is retained on various parts of the watershed in deposits of decomposed granite, which yield it in a very pure form during dry weather. These deposits have been proved to be upwards of 100 feet thick in several places.

The Burrator Reservoir is formed by two embankments, one of masonry across the narrow gorge through which the River Meavy flows, the other of earthwork lying between two hills known as Sheepstor and Burrator. It was expected that solid granite would be found on the site fixed upon for the masonry wall, and fortunately the supposition proved correct. In the case of the earth embankment, it was known that decomposed granite extended to a considerable depth, but it was not anticipated that it would be necessary to excavate, even in this material, to so great a depth as was afterwards found requisite. The peculiar geological features discovered in sinking the trench, however, made the baring of the solid rock a necessity for the purpose of securing a watertight barrier. The quantity of water impounded is 657,000,000 gallons, the area covered by water being 117 acres. The length of the reservoir is 1¼ mile, and the greatest width is ½ mile, the top water-level being 708 feet above Ordnance datum.

The Burrator Dam. (Figs. 2 and 3, Plate 1.)

The height of the masonry dam across the River Meavy is 77 feet, measured from the old river-bed to the overflow-level; whilst the total height from base of foundation to coping of

parapet-wall is 145 feet 6 inches. The excavated trench was 80 feet wide at the level of the river, and decreased in width on the valley sides in the same ratio as the thickness of the dam. The dam measures 62½ feet in thickness at the level of the river-bed, tapering upwards with a slope of 1 in 0·075 on the water face and 1 in 0·61 on the outer face. A roadway 18 feet wide is carried over the top of the dam on five segmental arches of 25 feet span. The length of the dam on top water-line is 361 feet, and the length of overflow is 125 feet.

The excavation was begun in November, 1893, and was practically completed by November, 1895, when building operations commenced. Fortunately, no timbering worth mentioning was required, as the ground was sufficiently hard to stand without it. After the overlying earth and boulders on the site had been removed, solid granite rock was found at depths varying between 2 feet and 40 feet. Several wide fissures full of deposited material ran through the rock, crossing the line of the trench in such a way as to afford an admirable means of tying the mass of the masonry into the foundation rock. The material in them, which increased in hardness with the depth, was excavated until a hard bottom was reached. The fissures were wedge-shaped, decreasing in width with the depth. When the granite was exposed, it was found to have many joints and cracks, some, particularly on the sides of the valley, being quite open, others being filled in by deposit. Excavation only ceased when every crack and joint had been followed down to the solid rock. The quantity of water draining into the trench from crevices in the rock was very small. When the jointed rock was removed, it was generally found that the water came either from one side or the other of the excavated trench, and not from the base on which the dam was to be built. The rock on which the dam is founded is a hard porphyritic schorlaceous granite with large crystals of felspar, forming a perfect foundation.

The rock taken from the excavations was, as a rule, cut by hand-labour with the double object (1) of obtaining stone in suitable sizes for building, and (2) of preventing the shaking and cracking of the rock beneath by the use of blasting materials. When building was commenced there were 12,000 cubic yards of granite in stock, taken from the excavations. A quarry was made within the reservoir at a distance of about 150 yards from the dam, from which the remainder of the stone required was obtained.

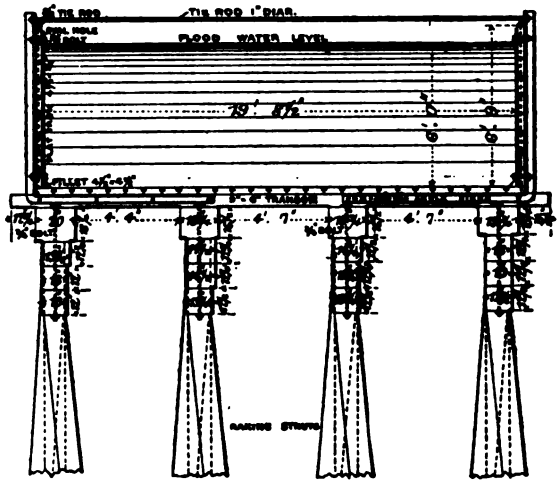
Before building was commenced the rock foundation was scoured and washed with water, and was afterwards covered

with a layer of sand and cement. Whilst the excavations were in progress, the river was carried overhead in a wooden launder or trough (*Fig. 4*) 120 feet long, 20 feet wide and 7 feet deep. The greatest flood which occurred during the 2 years this launder was in use did not fill more than two-thirds of its cross-sectional area at the inlet end.

Materials.—The whole of the stone used, both for facework and for making concrete, was granite weighing 165 lbs. per cubic foot.

Probably no material is more suitable for the building of a masonry dam. Its durability, compressive strength and weight,

Fig. 4.



Scale, ½ inch = 1 foot.

Cross Section of Launder at Centre.

the facility with which it is split, and, lastly, its effective appearance, are all exceedingly strong points in its favour.

The weight of the granite blocks built into the core of the dam, sometimes called "displacers" or "plums," ranged from a few hundredweight to 7 tons. Each block was roughly dressed on the bed, and afterwards was carefully washed and scrubbed with wire brushes before being delivered on the dam. The broken granite, being hard, gritty and angular, formed a perfect aggregate for the making of concrete. All stone that required to be cleaned was scrubbed and washed before being crushed. It was found that when the jaws of the stonebreakers were set to pass 1¼-inch stones, the quantity of sand produced was more than sufficient to

fill the interstices of the broken granite, and it was therefore unnecessary to add more. A cubic yard of the crushed granite contained :—

	Cubic Feet.
Broken stone (over $\frac{1}{2}$ inch)	10·24
„ „ (between $\frac{1}{2}$ inch and $\frac{3}{4}$ inch)	5·69
„ „ („ $\frac{3}{16}$ inch and $\frac{1}{4}$ inch)	2·56
Sand under $\frac{3}{16}$ inch	8·51
	27·00

Part of the sand required for the masonry was found in the bed of the reservoir. It was passed through screens and was afterwards washed. The remainder was made by crushing the granite.

The cement used was specified to stand a 7-days' test (including 6 days of immersion in water) of 300 lbs. per square inch. It was required to pass through a sieve of 1,600 meshes to a square inch without residue, and to leave not more than 10 per cent. of residue on a sieve having 5,800 meshes to a square inch.

Tests of cement briquettes made with various kinds of sand confirmed the fact that the sand made by crushing the rock was superior to any other. The briquettes made with crushed granite exceeded in strength those made of washed sand (produced by the natural decomposition of the granite), by 27 per cent., when mixed in the ratio of 1 of sand to 1 of cement. The average strength of the neat cement after 7 days was 526 lbs. per square inch, and the percentage left on the finer sieve was about 9, nothing being left on the coarse sieve. The strength after 1 month was 747 lbs., and after 1 year 909 lbs. per square inch. Some interesting results were obtained by making briquettes of concrete taken directly from the mixings on the bankers. The small size to which the granite was crushed permitted of such tests being made. The strength of 5 to 1 concrete at the end of 28 days varied between 274 lbs. per square inch and 358 lbs. per square inch, and averaged 319 lbs. per square inch. The neat cement (7 days) tests during the period of the concrete tests gave a strength of 522 lbs. per square inch. The specific gravity of 5 to 1 concrete when quite dry was about nine-tenths of that of the solid granite. In other words, 1 cubic foot of concrete weighed 150 lbs., whilst the weight of a cubic foot of granite was 165 lbs. The water absorbed by the concrete was found to vary between 1·22 per cent. and 2·67 per cent., whilst the granite absorbed 0·30 per cent.

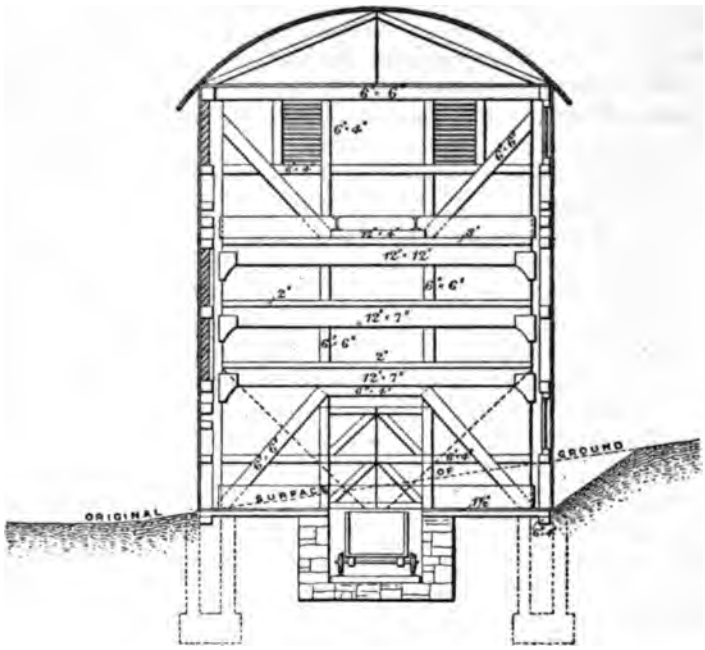
In order to find the specific gravity of the concrete used, blocks of various sizes were cut out of the interior of the dam, and their

bulk was ascertained by immersing them in water-tanks and measuring the quantity of water thus displaced. The weight of each block was taken before and after immersion.

Tests were made of the resistance of concrete blocks (9-inch cubes) to crushing. These blocks also were cut out of the hearting of the dam, and were tested at the age of 1 year, giving an average result of fracture at 220 tons per square foot.

The cement-sheds consisted of a store and an airing-shed. The

Fig. 5.



Scale, ¼ inch = 1 foot.

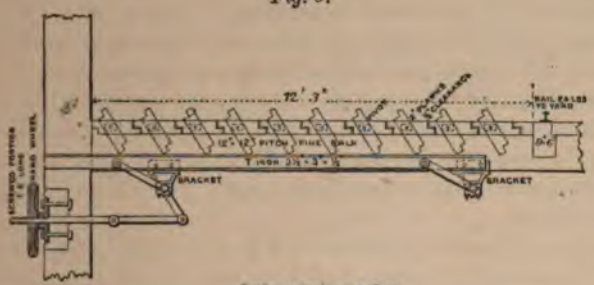
CROSS SECTION OF CEMENT-SHED.

latter was built against the side of a hill to allow of a road being run in level with the top floor, in order to facilitate the discharge of the cement from the wagons (*Fig. 5*). In the interior of the shed there were three floors, one above another, on which the cement was laid for airing before use. The floors were formed of 11-inch by 3-inch planks, suspended at each end by a pivot placed a little out of the centre of the plank end, so that when so suspended the flat sides of the plank were vertical (*Fig. 6*). By a mechanical contrivance hand-wheels on the outside of the shed were made to

raise the planks to a horizontal position when cement was to be laid on them, or to lower them to a vertical one when it was required to drop the cement to a lower floor, as necessary. Beneath the bottom floor were large hoppers. The cement either from carts or from the store was spread by hand on the top floor to a depth of about 6 inches, where it remained for about 24 hours, after which it was lowered to the second floor, and on the following day to the third floor, by the mechanism described. On leaving the third floor it fell into the large hoppers, which discharged into wagons by which it was delivered on the works.

Before commencing the masonry-work of the dam, the deep fissures and the inequalities of the rock foundation were filled with concrete. Upon the concrete large stones of irregular shape,

Fig. 6.



Scale, $\frac{1}{4}$ inch = 1 foot.

METHOD OF TILTING FLOOR-PLANKS OF CEMENT-SHED.

but with fairly flat beds, were separately set in a thick layer of cement mortar, and were thoroughly bedded by being slowly moved backwards and forwards by iron bars, and afterwards beaten down by heavy wooden malls. The stones set in this fashion were arranged to break joint one with another horizontally, and as often as possible vertically. The spaces between the stones were filled by 5 to 1 concrete carefully rammed into place. The horizontal space between one stone and the next was never less than 3 inches. The main object kept in view in executing this part of the work, apart from watertightness, was to secure as large a proportion of stone as possible in order to increase the weight of the dam. It is clear that the more labour spent in squaring the stones the closer they can be set, and the more this weight can be increased. In practice it will be found that the best stones go to the stonecutters to be prepared for facework, whilst the more irregularly-shaped stones are used as displacers; with the result

that unless a very considerable amount of labour is spent in squaring the more irregular stones, the proportion of concrete is greater than that of the stone, and the concrete being the lighter of the two the specific gravity of the dam is proportionately decreased. It is of course feasible to fill the spaces between the large stones with smaller ones; but it is questionable whether it is not a more expensive process, and in addition there appears to be more likelihood of the occurrence of leakage where there are so many joints. In building a masonry wall of any considerable length it is impossible in the ordinary course to continue working on the whole area at once. From various causes it was found more convenient to raise one portion a few feet high at a time, afterwards bringing up adjoining parts to the same or a higher level. Sometimes weeks passed before a particular level was raised again. In cases of this kind, and, indeed, in all cases where new work was joined to old, the surface of the concrete was broken by picks and the roughened face was afterwards brushed and washed. On this prepared clean surface a layer of cement mortar was placed in order to ensure a sound joint between the old and new work. Should this precaution be neglected the probability is that there would be little adhesion between the new and the old concrete, and what is worse, there might be leakage through the defective joint.

The granite facework of the wall was composed of large stones, having an average thickness of 30 inches, the length of the butt joint being 18 inches. The faces were left rough as they came from the quarry, the beds and joints being carefully worked. On the water face the vertical joints were tied together by a diamond-shaped cement joggle. For a height of 25 feet above the reservoir-bed, where the pressure was greatest, every joint on this face was rebated to a depth of 6 inches for a width of $\frac{3}{4}$ inch, making a joint about 1 inch wide.

All the water-face joints were filled with neat cement to within $\frac{1}{4}$ inch of the pitch line, and were caulked.

Culvert.—As already stated, during the excavation of the trench the river was carried overhead by a large trough or launder. When the masonry had been carried to a sufficient height a culvert of granite 10 feet in diameter was built, through which, subsequently, the river was turned. In order to break the straight joint formed by the parallel sides of the culvert, three recesses were made around it internally, each 2 feet 3 inches long by 9 inches deep. To increase the delivering capacity of the culvert during floods, it was originally intended to make it with a bell-

mouthed inlet; but the cost of executing this design in stone was so great that eventually the idea was adopted of casting a bell-mouth in segments and attaching it externally to the inlet. The greatest flood which occurred during the time the work was in progress did not put a head of more than 5 feet on the culvert when full. The filling of the culvert was done in the summer of 1898 when the river was very low. Owing to the fact that the leat at that time took for the town supply the whole flow of the river at a point $\frac{3}{4}$ mile higher up the stream than the masonry dam, it was only necessary in dry weather to deal with the water which gathered between that point and the dam, the area of this part of the gathering ground being 475 acres. A circular shield of wrought iron was placed over the mouth of the culvert—the cast-iron bellmouth having first been removed—and was kept in position by bolts let into the granite. A watertight joint between the shield and the stonework was made by a ring of india-rubber $\frac{3}{4}$ inch thick, which was placed in a recess in the stone face. The water in the river was then turned alternately through two circular holes in the shield 36 inches and 25 inches in diameter respectively, which corresponded with the sizes of the two outlet-pipes at this level. The outlet-pipes, which were of steel, were then laid through the culvert and bolted to the shield. To prevent any accident the shield was made strong enough to stand the pressure of the reservoir when full, in case, by any possibility, the pipes should become blocked. As it happened, no flood occurred to test it, the whole of this part of the work being executed, fortunately, in fine weather. The interior of the culvert was entirely filled around the pipes, the filling of the first 7 feet 6 inches from the water-face being composed of blue bricks in cement, and the remainder of concrete. Cement grout was injected into the concrete filling under pressure at intervals of 15 feet, and in this way any crevices at the top, as well as the upper part of the recesses already described, were entirely filled up.

Outlet-Pipes.—The outlet-pipes are three in number. One, 30 inches in diameter, which was used to carry the water flowing in the leat during the construction of the works, passes through the dam a little below the level of the old leat. The inlet level of this pipe is 28 feet below top-water line. It leads into an open chamber on the lower side of the dam, whence a pipe runs to the screen-chamber. The two other outlets are, as already stated, 36 inches and 25 inches in diameter respectively. A branch pipe 18 inches in diameter is carried upwards to within 20 feet of the level of the top outlet-pipe, in order that water may be drawn

from this level when necessary. All the pipes, where embedded in masonry, are of steel. Each outlet-pipe has a cast-iron bell-mouth—with gunmetal seating for cone valve—fixed vertically and attached to the steel pipes by a cast-iron bend. Screens framed by gunmetal angles cover the mouths of the outlet-pipes. The angles are bolted to the stonework of the forebay by ragged bolts of gunmetal. The screen itself is formed of tiers of brass tubes $\frac{3}{4}$ inch in diameter and $\frac{3}{4}$ inch apart. All metal-work under water, which would be likely to be damaged by corrosion and require replacement, is of gunmetal, brass or bronze. After passing through the culvert the 36-inch and 25-inch pipes enter the main valve-chamber. Here they divide into four pipes, the two in the centre continuing in a curve to the river for emptying purposes, whilst one of the remaining pipes leads to the screen-chamber, and the other joins the town-supply pipe directly, which is also connected with the screen-chamber. The discharging capacity of the three outlet-pipes is such that the reservoir can be emptied in $2\frac{1}{2}$ days.

Outlet-Valves.—The valves on the outlet-pipes are all worked by hand and are of three types:—

(1) Cone-valves, which are placed on the bell-mouthed pipes already described, through which the water from the reservoir enters the outlet-pipes; (2) Sluice-valves of the ordinary type with by-passes; (3) Sluice-valves with doors in two parts worked by separate spindles.

The cone-valves are specially designed to close the outlet-pipes in case the double set of valves on the lower side of the dam requires repair. They are worked by hand-gearing placed in a chamber built beneath the roadway over the dam. The larger valves consist of three and the smaller valves of two circular sections of cast iron forming a cone-shaped cover to the bell-mouth outlet-pipes. In closing, each section is lowered in turn on to its gunmetal seating, and in this way the concussion is minimised. The several sections of each valve are kept in place by vertical guides, and they are lifted and lowered by rods and chains of bronze.

The sluice-valves with by-passes are used in positions where it is possible to ease the raising of the valve by first opening the by-pass. It is of comparatively little use to place a by-pass on a valve which discharges into the open, but in a position where the valve discharges into a main which can be filled by the opening of the by-pass, so as to put a back pressure on the valve door, a great advantage is derived. For the 36-inch and 25-inch mains

discharging into the open, valves with two doors were used. The ratio of the area of the small door to that of the large one is 1 : 7. Where heavy pressures obtain and where space is not a consideration, it is probably more advantageous to use two or more smaller valves than one of large diameter.

Screen-Chamber.—The screen-chamber is placed on the lower side of the masonry dam, 53 feet below top water-level. The arrangement for screening the water is very simple. Eleven pitch-pine frames, 7 feet by 3 feet, are fixed against each side of the chamber, supported by angle-bars placed at an angle of 45°, the foot of each row of screens abutting against a saddlebacked granite stone in the centre of the chamber. The frames are covered with copper gauze having 1,600 meshes to a square inch. The water enters by two openings at the end of the chamber which lead under the screens, and rises through them, leaving any deposit on the lower side of the gauze. To clean the screens it is not necessary to remove them; the chamber is emptied, and a hose pipe is turned on to the screens, washing away any impurities, the dirty water passing from the bottom of the screen-chamber to the river. On leaving the screen-chamber, the water passes over a gunmetal knife-edge gauge-weir 12 feet wide before entering the town-supply pipe.

Gauge-Weir.—Immediately below the masonry dam a stone weir 4 feet high and 50 feet wide, with a gunmetal knife-edged plate on the top, is placed across the river, forming a gauge-basin. Training walls on each side of the river extend from the foot of the masonry dam to a few feet beyond the weir. By these walls the overflowing waters of the reservoir, which, on falling down the outer face of the dam, cover a width of upwards of 150 feet, are directed into the old river-bed. All the water, excepting that for the town, which leaves the reservoir either by the outlet-pipes or from the overflow, passes over the 50-foot weir, and its varying head is registered by a clockwork-recorder placed in an adjoining gauge-house. The compensation-water, which is only a small quantity, viz., 576,000 gallons per day, also passes over the weir; but as it could not be accurately measured over a weir of such great length, it runs along a collecting channel, after falling over the weir, to a small orifice-gauge placed below the centre of the weir. Before entering the gauge-basin the compensation-water is used to work one of Blake's hydraulic rams, which pumps 60,000 gallons per day to a height of 147 feet for the supply of a small village lying at a higher elevation than the reservoir can supply.

SHEEPSTOR EMBANKMENT. (Figs. 7, Plate 1.)

The trench for the Sheepstor embankment was 680 feet long, whilst the embankment is only 470 feet long. The width of the bank at the top is 12 feet, and the inner and outer slopes are respectively 3 to 1 and 2 to 1. The depth of water against the inner slope is 17 feet, the top of the bank being 6 feet above top-water line.

The watertight core of the embankment is of clay 6 feet in thickness at the top, increasing to 8 feet at the base. Below ground the watertight core is of concrete, forming a wall 5 feet in thickness, terminating at the top in a concrete shoe in which the clay rests. The cutting of the trench was commenced in August, 1894, and the embankment was completed in November, 1897.

Several trial pits were sunk in order to ascertain the most advantageous site for the trench, but eventually a line, which was practically that shown in the Parliamentary plan, was decided upon. Two of the trial pits sunk on this line, which had exposed rock at a depth of about 14 feet, gave somewhat delusive results, since on the opening up of the trench they were found to be situated over pinnacles of rock which shelved away rapidly to considerable depths. At a few feet from the surface water was found, and pumps were required to keep the trench clear. The water increased in quantity with the depth, until the pumps were lifting 450,000 gallons daily to a height of upwards of 100 feet. The trench, which had a depth in the centre of 105 feet, was a most interesting one. It was cut through an extensive layer of decomposed granite, and the sides of the trench exhibited a remarkable variety of colours. The decomposed granite had no distinctive colour throughout, but varied every few yards. A vein of white china-clay crossed the trench near its deepest part, and at several different points veins of red elvan were cut into.

It is generally assumed, although it would appear difficult of proof, that the so-called decomposed granite was originally in a hard state, and that its present condition is due to the gradual disintegration of the constituents of the coarsely crystalline granite by the percolation of surface-water. A theory was advanced by an eminent geologist at the time when the construction of the reservoir was first contemplated, that possibly the change in the condition of the granite was caused by chemical action from below. This theory would seem to imply that the chemical action

took place upwards through rifts and cracks in the rock, and that therefore the decomposed material might be expected to extend downwards. On reference to the geological section it will be seen that the solid rock was found beneath the layer of decomposed granite along the whole length of the trench, but at greatly differing depths, the deepest point being not far from the middle of the valley. It was observed that, as a rule, as greater depth was attained the decomposed granite became harder, until it gradually merged into the hard rock; but in some cases the transition from soft to hard rock was sudden. Whilst cutting through the decomposed granite, rounded granite boulders were found with concentric rings of decomposed rock, the outer rings being soft, whilst the inner rings increased in hardness to a solid core. In other cases the concentric rings were found but the core was soft. Mr. Ussher, of H.M. Geological Survey, assures the Author that the disintegration of the granite invariably proceeds from the surface downwards, and that the boulder masses are simply harder patches which have remained *in situ* among the disintegrated materials.

Probably the point which will most forcibly strike an engineer who examines the plans of this dam will be the great depth to which the trench was carried in comparison with the small head of water against the embankment. The reason for this comparatively great depth will now be explained.

On the geological plan and section are shown by thick and thin black lines the position and width of veins of rock, sometimes granite and sometimes quartz, which intersected the trench, generally at an angle between 45° and 70°. Usually these veins were practically parallel, trending N.W. and S.E., although others of small size were found, which, in other directions, intersected the former. The veins ranged from 1 inch to 3 feet in thickness, and the larger had the appearance which would be exhibited by the section of a dry rubble wall of irregularly shaped stones fitting one into another. In other words, the veins consisted of vertical walls of broken rock with open joints. These veins were the main reason for so deep a trench being sunk. Had they been of solid rock, probably no difficulty would have arisen from them, but under the circumstances they simply formed deep land drains. That they did act in this capacity was shown by the fact that the upper stones of the veins were deeply stained with peat, carried down by the surface-water, but the stains gradually disappeared and the stone became quite white as greater depths were reached.

In sinking the trench there was no certainty that solid rock would be found, nor was it known whether, supposing the solid rock were reached, the veins would terminate in it or would continue. At a depth of 70 feet there was no favourable change in the appearance of the two largest veins, their joints being still wide open and the blocks loose, and where they crossed the trench streams of water rose continually from them. About this time it was noted with satisfaction that one of the smaller veins, in a shallower part of the trench, had apparently terminated in a bed of solid rock, which gave rise to a hope that the others might run out in the same way. As the sinking proceeded it was seen that the water which had formerly bubbled up like a strong spring in the bottom of the trench was coming more and more from the sides of the trench, and at a still greater depth it was found to be entering the trench a few feet above the bottom and running down the sides, none coming in at the bottom of the trench. Deeper still the decomposed granite became harder, until—particularly where it adjoined the veins—it was very difficult to excavate. The joints between the stones in the veins became filled with an argillaceous deposit and decreased in number. Then the narrow streaks of clay which had been observed vertically on either side of the veins, and which lay between them and the adjoining granite, disappeared, and the vein became one with the granite (so far as engineering purposes were concerned), although its course through the latter was plainly marked. In following down two other veins water continued to flow upwards from holes in the hard quartz rock of which they were formed, and in these cases pipes were placed over the springs, and were carried up above the water-level of the reservoir.

The termination of the veins in the rock was not always as is described above. In several instances veins 6 inches to 12 inches wide in the decomposed granite appeared to terminate when the solid granite was bared, but on closer examination of the bared rock a black line about an inch wide could be observed, which continued downwards through the rock, beneath the centre of the vein. Near the east end of the trench there was quite a network of small veins, which crossed one another in every direction, necessitating the trench being sunk to a depth of 60 feet to 70 feet before the rock was found. At the east end the depth was 40 feet, and here the concrete is tied into decomposed granite, the trench being bottomed in solid rock and carried some distance into the hillside.

It is very probable that had not the veins just described

existed, the trench would not have been carried so deep, but would have been bottomed in decomposed granite at a much less depth; but in that case risk of leakage would have been greater, in fact it is almost certain that water would have slowly drained through the decomposed granite along the whole length of the trench. However, as the difference in level between the reservoir top water-line and the level of the subsoil water behind the dam is only 13 feet, it is not likely that it would have done any damage, the pressure being so slight.

On the completion of the excavation of the central part of the trench, the surface of the rock was washed clean and covered with a layer of cement and sand, on which a layer of concrete was spread across the whole width of the trench. On this layer a concrete wall 5 feet thick was carried up. The water-face of this wall was supported by a framing of 3-inch tongued and grooved planks held in position by struts against the side of the trench. As every batch of concrete was put in, sand and cement gauged 3 to 1 was carefully worked down between the concrete and the planks, making a facing about 1 inch thick against the smooth surface of the plank. It was generally arranged, in order that the joints between the new and the old concrete might receive proper attention, that the portion of the wall on which work was being concentrated should be carried up in as thick a layer as possible at one time, but not exceeding 3 feet, the height of one plank framing. On the completion of a layer, V-shaped depressions were made in it longitudinally by pressing timbers 4 inches by 4 inches, cut across the angles, into the soft concrete, in order to break the joint between the layers. Concrete which had already set was always prepared by being roughened with a pick; it was then washed clean and covered with a layer of cement and sand, before any newly-mixed concrete was laid on. The considerable quantity of water flowing into the trench even in the driest weather was the cause of much trouble, and every attention had to be paid to it in order to prevent damage to new concrete. In cases where it was necessary to allow the incoming water to rise over newly-made concrete, small wooden troughs were used, and as a rule the water was kept moving so slowly as to prevent the cement from being washed away to any extent.

Pipe-Line.

The pipe-line from the Burrator Reservoir to the first service-reservoir at Roborough, south of which the leat had already been

abandoned, was commenced immediately after the Act of Parliament was sanctioned. This line of pipes, $4\frac{3}{4}$ miles in length, was intended to take the place of that part of the old-fashioned leat—8 miles in length—which was still in use, and which, on several occasions, had been blocked by ice and snow in winter, entailing great inconvenience and expense. It was completed in May, 1894, fortunately in time for use during the very severe frost of the following winter, when, no doubt, the leat would have been frozen for several weeks, and the supply of water to Plymouth would have been stopped entirely, as it was in the winters of 1881 and 1891. The pipes are 25 inches in diameter, forming an inverted siphon with a mean hydraulic gradient of 1 in 334. They are capable of delivering 11 million gallons per day from the Burrator Reservoir into the Roborough Reservoir when the former reservoir is full, and 8 million gallons per day when the Burrator Reservoir contains only 10 feet of water. The pipes are of different thicknesses, ranging from 0·82 inch to 1·125 inch, according to the pressure. The ends are turned and bored, excepting every sixth pipe, which has a common socket, to allow for settlement. Double air-valves are fixed on all elevated points, and scour-pipes in the depressions. Sluice-valves provided with 6-inch by-passes are fixed at every $\frac{1}{2}$ mile. There has been no trouble from air in the pipes, owing no doubt in a great measure to the fact that they are laid to gradients, which method, whilst being perhaps a little more costly, amply repays the extra labour by the more regular and even jointing of the pipes, and by the facility with which any imprisoned air travels to an air-valve and so escapes.

The pipe-line passes under the Launceston branch of the Great Western Railway in a culvert 7 feet 6 inches in diameter. The railway at this point runs along the foot of a hill about 200 feet high, and, as the line of pipes, after crossing the railway, ascends the hill, precautions were taken to prevent damage which might result from the sudden bursting to which cast-iron mains are liable. From the lower side of the culvert to the top of the hill the pipes were made of riveted steel plates, $\frac{1}{2}$ inch thick, with flanged joints. In making the joint the connecting-bolts (20 in number) were put in position, leaving a space of $\frac{1}{2}$ inch between the flanges. This space was then run with lead, and the bolts were tightened up. At each end of the length of steel pipes is a manhole for inspection purposes. The greatest head of water on the pipes is at the crossing of the River Meavy, where it is equal to 350 feet.

Compensation.

As already stated, the area of the watershed is now 5,360 acres. Compensation-water is given to the river to the amount of 576,000 gallons per day. Fortunately for the Plymouth Corporation the Act of Parliament obtained in the year 1585, whilst affording protection to the owners of the lands through which the watercourse was to be carried, and to whom there is reason to believe compensation in one way or another was paid, does not seem to have been drawn with the object of compensating the riparian owners of the river from which the water was to be abstracted, who, considering themselves aggrieved, complained of their loss to Parliament. Sir Francis Drake, possibly because he knew more of the matter than anyone else (since he had made the leat) was appointed chairman of a committee of enquiry, which does not, however, appear to have given the owners any redress. Had the Plymouth Corporation been 300 years later in making its application to Parliament, it is not too much to say that compensation-water to the extent of at least 3 million gallons per day would have been required in respect of the watershed of 4,885 acres, the water-rights of which were acquired by the Act of 1585. The selection of this watershed was undoubtedly a good one. The waters of the Meavy are pure and clear, approaching to rain-water in softness; they are not stained with peat, like adjoining streams, except in times of flood, when they rapidly clear themselves; and, in addition to these advantages, the dry-weather flow of the stream is extraordinary in quantity, being between 50 per cent. and 100 per cent. above the flow from neighbouring watersheds per unit of area. In fact, during the last 9 years, which include several years of unusual drought, the flow has never fallen below 1·09 cubic foot per second per 1,000 acres.

Cost.

The cost of the works, including land, was £178,000. The masonry dam, with screen-chamber, valves and valve-houses, measuring-weir and recording-house cost £102,000, whilst the earthen dam cost £24,000. The pipe-line, including one railway and two river crossings, valve-chambers, etc., cost £23,500.

The Paper is accompanied by 10 tracings and a map, from which Plate 1 and the Figures in the text have been prepared.

Discussion.

The President. The PRESIDENT thought the members would agree that the thanks of the Institution were due to the Author for the clear description he had given of the work referred to in the Paper.

The Author. The AUTHOR, after having exhibited views illustrating the progress of the work, mentioned that the cost of the core of the dam, including facing, was 35*s.* 0*d.* per cubic yard; and, including the archways and the roadway over the top of the dam, 37*s.* 6*d.* per cubic yard. There had been considerable trouble in the filling of the reservoir; the decomposition of the grass, trees, tree-roots, shrubs, etc., had caused the water to turn to a most objectionable colour, and had given it a very unpleasant odour, and for 3 or 4 months the water-engineer and the people of Plymouth had had a most unpleasant time.

Mr. Hill. Mr. E. P. HILL remarked that it was always a pleasure to listen to an account of work as well designed and well executed as that described in the Paper. Although it was not unusual, there was no statical advantage in putting a batter on the water face of the dam until a depth was reached of about 70 or 80 feet below top water-level. He wished to ask whether the Author had had any particular reason for filling the culvert solid from end to end after the pipes had been laid. It would obviate the danger of a burst pipe, but there might be some difficulty in replacing any pipe supposing it were desired to do so on account of corrosion or for any other reason. A measuring-weir about 130 feet from the toe of the dam was shown on the diagram, and it appeared to him that the water falling over a very steep dam would create such a surging in the pool above the weir that it would be extremely difficult to measure the discharge of the weir. A point which was rather neglected arose incidentally out of the Paper. The average annual rainfall over a long series of years, the drainage-area, and the capacity of the reservoir were stated; but neither the daily quantity of water which it was hoped to obtain from that area, nor the relation between that daily quantity and the capacity of the reservoir were indicated. He was well aware that there was a conventional method of treating those matters, and no doubt this case had been treated in that way, but at the same time he should like to draw attention to the very

great importance of being able to form a really reliable estimate of the yield of a gathering-ground and the reservoir capacity which was necessary to guarantee that yield, because he did not think the information available at present was adequate to enable such an estimate to be formed. Any rational calculations made for that purpose must be based upon either the assumed or observed rate of flow from a drainage area throughout the severest drought. That rate of flow would be admirably given if it could be obtained by an autographic record in connection with a stream-gauge, a continuous diagrammatic record, but unfortunately there were great difficulties in the way of obtaining such a record. In the first place, instructions were usually given for a waterworks scheme only a short time before it was necessary to go to Parliament, and as the driest 3-year period only occurred about once in 40 years, any observations that might be made on the flow of the streams in the time available would be really of no value whatever. Again, there was no power to enter on land to establish gauges, and the cost of efficient gauges for measuring the maximum flow would be very considerable if the drainage area were large. The channel leading to the gauge would probably be filled up with wreckage after every flood, and records taken under such conditions could not be interpreted. Also the variation of the flow, which might be between $\frac{1}{2}$ inch and 6 feet in depth, would introduce great difficulties in the way to a satisfactory result, and would really take the discharge out of the range of any previous experiment and make it difficult to form a reliable estimate of the quantity passing. Therefore it was necessary to fall back on the rainfall method, although it was but a poor substitute. That method only professed to state what quantity of water could be obtained from a gathering-ground if adequate storage accommodation was provided. It gave no idea as to the meaning to be attached to the word "adequate," or of the necessary size of the reservoirs. Four-fifths of the average annual rainfall as estimated or observed over a long period was taken in order to arrive at the average rainfall of the three driest consecutive years, an assumption which came out wonderfully closely when long records were available. A deduction from that quantity was then made, varying usually between 12 inches and 16 inches, representing the loss by evaporation and absorption, and the resulting figure was the available rainfall. Year after year schemes were taken to Parliament based on such calculations; no question was ever raised as to the "three years" period, and very little as to the amount of evaporation to be deducted. He

Mr. Hill.

Mr. Hill. did not say that the present practice was wrong, but that there was not sufficient information available to show whether it was really right or wrong. It was quite probable that the method led to correct results in intermediate cases, but it was not known how far towards either end of the scale the method was really applicable. It told nothing at all as to the storage accommodation to be provided. It would hardly be believed by those who were not waterworks engineers, that throughout the Institution "Proceedings," so far as he was aware, there was not a single recorded instance of any experiment having for its object the estimation of the loss from evaporation and absorption over a large and varied drainage area. In fact he knew of only one experiment of which a record had been published. The question had been discussed before the Duke of Richmond's Commission on Metropolitan Water Supply, in 1869, and three witnesses of the highest standing, Mr. Thomas Hawksley, Mr. Bateman, and Mr. Duncan, had given evidence upon the question. They had all made experiments. The Commissioners had not been satisfied that that was the right way to attack the question; they had put it to the witnesses whether instead of calculating the rainfall they ought not to have gauged the streams; and they had asked for particulars as to how they had arrived at their deduction for evaporation. The three witnesses had replied that numerous experiments had been made on many drainage areas with the results they had stated, but they had not given any details of those experiments, and therefore it was impossible to form any opinion as to their absolute value. In after years one of those three witnesses, Mr. Bateman, had published the experiments upon which his evidence had been based. They were described in his book on the Manchester Waterworks, and were based on observations made while those works were in progress. Mr. Bateman's drainage area had been 15,000 acres; he had had only three rain-gauges, placed at elevations between 500 feet and 600 feet above Ordnance Datum, while the mountains around rose to over 2,000 feet, and being aware that those gauges could not possibly represent the average rainfall, he had added, as a pure conjecture, 10 per cent. to their readings; after thus lumping on about 5 inches, he had actually worked out his figures for the evaporation to three places of decimals! Another important element of Mr. Bateman's calculation was the quantity of water which ran to waste over the waste weirs, but the way in which that had been observed was not given. He believed, however, that Mr. Bateman had had it observed only once a day, and it was obvious that a

single daily observation could not possibly be a reliable indica- Mr. Hill.
tion of the total flow over the waste weir during the 24 hours. Yet another element in the calculation was the quantity of water which was sent to the town from the drainage-area. The point at which the supply to the town had been gauged included supplies from that drainage-area and from another drainage-area of 2,300 acres, and Mr. Bateman had not known at all what portion was derived from one or the other. Again, however, assumption took the place of observation, and he had assumed that 2 million gallons per day were derived from the second drainage-area; and, after that long string of assumptions, Mr. Bateman had thought it worth while to state his result (the loss from evaporation, &c.) to three places of decimals, and to tell the Commission that it was really a measured quantity! After experiments like that, by a really distinguished waterworks engineer, engineers would begin to wish they had the observations on which the calculations made by the other engineers also were founded. He repeated that it was a very singular thing that there were no published records of the determination of such a fundamental element in the calculation of the yield from gathering-grounds. With regard to the proportioning of the storage, which was the second most important element, he believed that the late Mr. Thomas Hawksley's convenient and useful formula was generally used, and its truth assumed. But there again he was not aware, although he might be wrong, that the experiments upon which that formula was based had ever been published. He did not say that that formula would not be justified by results in what might be called average cases, but a doubt arose as to its applicability in the extreme cases of low rainfall on the East Coast and high rainfall in such places as Cumberland. The formula did not profess to take into account the steepness of hill-sides or the nearness of the rock to the surface, characteristics which must have considerable influence in determining the storage capacity to be provided. It might be said that if waterworks had been constructed on wrong assumptions, the matter would soon have been heard of. That did not follow, because waterworks were constructed to give a certain daily quantity during the three driest years, and that period only came perhaps once in 30 or 40 years, and then it came and went without any daily observation being made—like an eclipse of the sun for which no arrangement had been made by astronomers. It was impossible to learn by failure, because there were no materials by which failure could be estimated. And yet there were many waterworks in charge of competent engineers

Mr. Hill. where most valuable experiments on these points might be made. They would have to be continued year in and year out in the same way that Mr. Symons's rainfall returns were continued. It would be necessary to establish a number of rain-gauges over the drainage-area to be tested so as to give a proper representation of the rainfall on that area, and it would be necessary to provide recording apparatus at the weirs. Such things cost money, and could hardly be undertaken by private enterprise, and that was why there was so little information on the subject. Local authorities were extremely unwilling to vote any money without seeing a direct return for it. A thing such as he suggested could only be done in combination. Waterworks engineers had really done very well, considering how little they could do in the matter, having regard to expense. If the local authorities were properly approached, say, by the Council of the Institution, aided perhaps by the Royal Society or the Local Government Board (both of whom were interested parties), something might be done. If it were possible to show them that any proposal was part of a well-considered and well-directed scheme to remedy the want of information, and a scheme in which they and not the engineers were directly interested, perhaps they might consider it favourably. In an isolated case they would naturally say, "If the engineer wants the information let him pay for it." He would like very much to put a proposal most respectfully before the Council of the Institution, namely, that, either by themselves or by a Committee, they should select about thirty suitable waterworks for a beginning and send a circular round to the engineers in charge of them, asking whether the works were adapted for such experiments, or could be adapted at the expense of the local authority, and whether they were willing to supervise the experiments and to send in an annual balance-sheet. At present the state of affairs was like that of a man with a banking-account who never saw his pass-book; nothing was known of the quantity of water received or expended, or of what size the balance at the bank, *i.e.*, the reservoirs, should be. Such returns might be sent in every month; when checked and corrected by the Committee they might be published each year in the Institution "Proceedings." By that means some most valuable information would be obtained, and knowledge of how the circumstances varied between the East Coast and the West Coast, on drainage-areas where there was little or no cover on the rock and where the rock was covered by a considerable depth of drift, and in dry seasons and wet seasons; there would gradually be collected a considerable body of infor-

mation on which to base waterworks calculations. The subject was no doubt somewhat elusive in its character, like meteorology, but that was a reason why there should be more and not fewer observations. Lastly, he hoped experiments would be always demanded, and not what was vaguely called "experience." It was often said, when a reason was asked for a certain thing being done, that it was the result of experience. Experience meant nothing at all unless it meant experiment, and, therefore, if any one made a statement of this kind he should bring forward his experiments, and it would then be seen whether they proved what he thought they proved. When a man had to publish anything he was much more careful over it than if he had merely to satisfy himself. Finally, he earnestly hoped that his suggestion as to the systematic observation of the flow of streams, and publication of the records would be taken up and realised by the Council. Mr. Hill.

Mr. CHARLES HAWKSLEY, Vice-President, congratulated the Author on having turned out so successful a work as the Burrator Reservoir. The site for the masonry dam had fortunately proved very satisfactory, though in the site of the earthwork dam some of those difficulties had been met which waterworks engineers only too frequently had to encounter. With regard to the design for the Burrator Dam which had been referred to in the Paper as not having been finally carried out, he might mention that his father had been responsible for it, and that it had not been carried out for purely local reasons. It had happened that feeling in Plymouth in regard to waterworks matters for many years had run very high, and the question whether the schemes proposed were really the best for waterworks purposes had little or nothing to do with the question. It had been entirely governed by feeling, rational or irrational—a great deal perhaps of the latter. His father had suggested a dam on the Burrator site where the dam had now been erected by the Author, but he had been told by the then Chairman of the Waterworks Committee never to mention the name again, the proposal having not fitted in with the party politics of the Water Committee of the time. The matter had gone on year after year, and Plymouth had suffered very much from droughts until, after 36 or 40 years had elapsed, the present works had been built. He thought the town had had, at one time or another, almost sufficient reports to construct the dams of! As to the structure, no doubt the Author would explain why the tunnel had been completely filled up and not merely stopped. He was not sure whether the weir was intended to be a gauge, or Mr. Hawks

Hawksley. whether it was merely a sort of receptacle to the water as it came over the face of the weir. He thought, from the Author's descriptions, that the screens were not in duplicate, and in that case he supposed the water-supply was temporarily shut off during the process of cleaning. Of course, Plymouth would derive its supply from the service reservoirs, and probably no harm would result. He agreed with Mr. Hill that very much more information might be obtained if those who had the control of waterworks undertakings were willing to pay for what, in their view, brought no return. His father had been accustomed to say that a board of directors or a local authority were willing to pay for a load of bricks but not for a load of brains. Many of them always resisted any expenditure for obtaining information which they regarded as being of very little practical use, because they did not realise its object. It was necessary, in looking back, to take into account the state of knowledge at the time earlier observations had been made, and not to judge the results by the advanced state of knowledge arrived at after 40 years' additional experience. He quite agreed that many of the observations proposed would be very useful, but it must not be overlooked that there were circumstances—such as rate of inclination of the ground, its nature, etc.—which would affect the returns obtained; and perhaps conclusions to an unduly high degree of refinement might be derived without sufficient ground, from observations which would, however, if properly applied, tend to increase knowledge. It was open to question whether such statistics, unless the conditions were carefully examined, were always reliable. Not very long ago he had had occasion to examine the returns of some rain-gauges for some years back, and he had been struck by the similarity between the records of some half-dozen gauges. Enquiry had been made, and it had turned out that the man who had charge of the gauges had saved himself the trouble of taking the individual records. He had taken the record at one gauge, and had then made slight alterations to show what he thought ought to be the records on the other gauges, and this had gone on for some years before it had been detected. That kind of thing was always liable to occur in any observations which were entrusted to men untrained in scientific methods of observation.

Mr. Deacon. Mr. G. F. DEACON considered the Author had set an excellent example to those who were on the spot, and saw from day to day the progress of works of that description, in the records he had made and preserved of the ground through which the trenches

passed. So far as he knew, that was the most interesting record that had ever been made of a cutting through decomposed granite. He had had the pleasure of visiting the valley before the matter had come before Parliament in 1890, and the site was a puzzle to any waterworks engineer. The decomposed granite was a remarkable phenomenon. It had been conclusively proved by the work that the origin of the decomposition was from the surface, and not from gases issuing from the earth below, as had been frequently supposed by geologists. He had been rather surprised to see that Mr. Sandeman had adopted in masonry of the kind employed the old-fashioned diamond toggle. There was not very much in the cost of it, but he thought the roughness of stone such as was used and Portland cement joints were quite sufficient without it. He noticed that after 28 days the strength of the Portland cement mortar varied in tension between 274 lbs. per square inch and 358 lbs. per square inch, which was not materially different from the strength which he had for many years past obtained by means of hydraulic lime mortar. Of course, such hydraulic lime was not capable of being advantageously used for all classes of hydraulic work, but for masonry dams, where the maximum pressures were not reached until long after the work required to sustain them was completed, there was no reason whatever why hydraulic lime should not be used. It required precautions, but those precautions were not difficult to secure, and the result was a material which after a few years attained the strength of Portland cement mortar, and had some advantages which Portland cement mortar did not possess. It was the greatest possible satisfaction to be able to come back to work left for several days, and to find that the surface could be worked up again without any material loss of strength, so that there was no imperfection of bond with the next course. The settlement was much slower, and consequently when it was completed there were fewer internal strains than with a quick-setting material. He had not a word to say against Portland cement, which he used very largely and had used exclusively in the Vyrnwy dam, but the more he used hydraulic lime the more satisfied he was that for many purposes it might be adopted with advantage in preference to Portland cement. The only disadvantage which he knew when the nature of the work gave sufficient time for slow induration, arose from the circumstance that if not properly protected during construction, a slow-setting material was liable to be affected by frost for a longer time than a quick-setting material. Mr. Deacon.

The PRESIDENT asked the relative cost per cubic yard? The President

Mr. Deacon. Mr. DEACON stated it was approximately 5*s.* to 7*s.* less as concrete.

Mr. Hill. Mr. E. P. HILL asked how the hydraulic lime was tested?

Mr. Deacon. Mr. DEACON said it was tested exactly in the same way as Portland cement. He had made that statement to many other engineers, and had more than once received the answer that hydraulic lime could not be tested in that way, because it cracked. Of course, precautions were necessary to prevent a condition which induced subsequent slaking and expansion. The time was too short to explain methods, but it could be easily done by grinding. It could not be done by grinding the lime with the sand, as really under the ordinary edge-runner; that was not a grinding process, but an amalgamating process; there was no pretence that the runners touched the revolving table; they were separated by the mass of the material, and there was no crushing of the particles of lime. If the particles of lime were crushed in a proper mill in the process of slaking, before they were mixed with the sand, an impalpable paste was obtained, the whole of the refractory particles in which had been thoroughly slaked at the same time as those which slaked freely, and with which, therefore, there was even less expansion than with Portland cement. With respect to Mr. Hill's observations upon the want of exact knowledge of the subject of flow off the ground, he appreciated the difficulties Mr. Hawksley had expressed, but he felt also that it was of the utmost importance to hydraulic engineers that more exact statistics should be obtained of the flow off the ground, and its relation to the rainfall. So far as he knew, the only experiments which had been made and recorded on a large scale in this country were those at Lake Vyrnwy, where for 9 years the records had been kept, and also on the Severn at Worcester, where the same thing had been done for nearly the same period. Those observations were quite continuous. Records of the height of the streams were taken automatically on diagrams, and the rainfall was observed by a very large number of rain-gauges. On the Vyrnwy area there were something like 30 on 24,000 acres. The records had not been published, but he hoped to publish them some day.

Mr. Marsh. Mr. C. F. MARSH did not quite see the necessity for the bell-mouth in the culvert. With a coefficient of 0·98 for a bell-mouth, and 0·82 for the culvert without a bell-mouth, there was only a difference of 2 feet 2 inches in the head of the water on the culvert had there been no bell-mouth, to discharge the same quantity as a 5-foot head on the bell-mouthed culvert, which

the Author gave as the greatest observed; and it seemed to him that the dam would very probably have been built up to that height before a flood occurred. If the Author objected to the cost of the granite bell-mouth, why have the culvert lined with granite? it was a great waste of material to build the whole culvert of granite; it might just as well have been built of concrete, and would have been then homogeneous with the dam, and could have been brought up with it. If it had been intended to fill in the culvert, which he supposed had been done, as the pipes would be under pressure, on account of the use of the cone valves of peculiar construction which had been introduced instead of a tower, it seemed a great pity to put in dressed stone for a lining. With regard to the Sheepstor trench, the Author had used a very curious filling; he had filled with concrete and had brought up puddle with it. Mr. Marsh did not quite see the necessity for both puddle and concrete. If the concrete had been carried up alone there would have been no more leakage through it, and probably a good deal less than through the decomposed granite if founded on that, which the Author admitted would have been done if there had been no fissures. The concrete had been carried right up, with puddle at the side of it for some part of the way. If the puddle was necessary, why not carry it to the top? In addition the Author had put a facing of 3 to 1 mortar in front of the concrete, which he did not see the necessity for; it seemed to be taking precautions which were entirely unnecessary. Mr. Hill had remarked there was no need for a batter on the front face of a dam until the depth of 80 feet had been reached. He thought, however, there was need. The addition of the top width would surely necessitate a batter before that, though it would be a small amount, nothing like the amount the Author had employed. In connection with the cone valves, he wished to ask what effect soft water such as that of the Plymouth supply had upon the steel pipes, as he believed soft water had a greater effect on steel than hard water. With regard to the strength of concrete made with crushed granite, tests often proved the sand from broken stone to be better than river-sand for this purpose, and in some cases showed that it was even advisable not to screen out the dust—possibly because the small particles of the latter were really very angular. He believed some engineers considered that sand from crushed stone was not as sharp, and therefore not as suitable, as river sand; but with any hard rock the sand from the stone-breaker would probably be sharper than the river-sand of the locality which was probably from the same kind of rock, and had had its sharpness impaired by attrition.

Mr. Marsh.

Mr. Marsh. Where tests proved that the sand from crushed stone was better than, or as good as, the river-sand, it was surely advisable to use it, particularly where river-sand was difficult or expensive to procure, as it saved the screening of the crushed stone for concreting purposes and the expense of procuring, and in most cases washing, the river-sand. There was seldom an excess of sand in the broken stone for the making of good concrete. The Author's tests of the cement, which showed 42 per cent. increase of strength between 7 days and 28 days, proved the very excellent quality of the cement used, and also the thorough efficiency of the method employed in airing. The tests for the tensile strength of the concrete as mixed on the stages were very interesting, the lowest test showing that the concrete would bear a tensile stress of 17·6 tons per square foot at 28 days. This proved that an ample margin of safety was obtained if the lines of pressure with the reservoir full and empty cut, respectively, the outer and inner extremities of the middle third of every joint; and that, at any rate, the primary triangular section might be safely designed on this principle (as the addition of a top width added also materially to the stability of the dam when the reservoir was full), and the base, as originally calculated, might even be somewhat decreased in width in some proportion to the width added at the top. With regard to the crushing strength of 9-inch cubes of the concrete used, which had been cut out of the dam and tested after 1 year, it would perhaps have been better if the Author had given the lowest test instead of the average; but taking 14 per cent. less than the average for the lowest, which figure was obtained from his tensile tests as given before, the lowest crushing strength would appear to be about 190 tons per square foot. Mr. Marsh believed the lowest crushing test for similar blocks out of the Vyrnwy Dam had been 187 tons per square foot. These results seemed to show that a greater compressive resistance might be safely allowed than 6 tons to 12½ tons per square foot, which was, he believed, generally adopted. The adoption of a higher limit in compression would materially increase the maximum height for low dams. In the present case, taking the specific gravity of the dam as 2·5, which appeared to be its value from the Author's experiments, and taking the maximum safe limit now employed as 12 tons per square foot, the limiting height for a low dam would be 123 feet, whereas, if 18 tons per square foot were allowed, the limiting height would be increased to 185 feet. Cone-valves such as the Author had used appeared to have been employed to save the expense of a valve-tower, but the pipes

through the dam were charged with high-pressure water, and were built in apparently for this reason, although, with the pressure they would have to bear, there did not seem to be any necessity for this. If a valve-tower was used, the pressure was taken off and the outlet-valves from the tower and the pipes were open for inspection at any time. A tower, if properly treated, added considerably to the picturesqueness of a reservoir, and also, the culvert being left open at the outer end, that face lent itself to æsthetical treatment. The multiple-valve arrangement insured great ease in manipulation, but the fact of the outlet-valves and pipes from the reservoir not being so accessible for inspection was a distinct disadvantage, and he was not sure that the tower as generally employed was not the better arrangement. A gun-metal plate was rather a refinement for a 50-foot weir in such a position as this one close to the bottom of the dam. With regard to the 3 to 1 mortar facing to the concrete in the filling of the Sheepstor trench, it would be interesting to know whether the Author had found that the stones from the concrete had been pushed through the inch of facing by the men who had worked the 3 to 1 mortar in behind the shuttering, as, unless the men had squeezed themselves into the 9-inch space left between the shuttering and the side of the trench, they must have stood on the green concrete in order to work in the facing. It would also be interesting to know what was the covering to the water-face of this embankment; it appeared from the section (Fig. 7, Plate 1) to be concrete slabs. The Author did not mention the leaving of any vertical keys at the ends of the layers of concrete, which seemed to be as necessary for baffles and ties as the longitudinal V-shaped keys. Plymouth seemed to be exceptionally fortunate in the matter of compensation water, which appeared to be less than one-fifth of the lowest recorded flow from the watershed.

Mr. Marsh.

Mr. John Hopkinson asked how the Author arrived at the rainfall of between 58 inches and 60 inches per annum. There were now ten or eleven gauges on the area which formed the gathering ground of the Burrator Waterworks, but there were only six gauges which had a record for so long a period as seven years, viz., 1893 to 1899. Those six gauges gave for that period a rainfall of 52½ inches, and the greatest difference between them was under 5 inches. The gauges, of which the record was not quite complete for the seven years, were mostly on rather higher ground; but, curiously enough, with these gauges the rainfall was really less than with those for which there was a record of seven

Mr. Hopkinso

Hopkinson. years. In a Paper[1] read before the Institution, Sir Alexander Binnie had shown that, although it was not possible to rely upon such a short period as this, a period of 35 years could fairly be relied on to give a trustworthy average. The only gauge with so long a record within a reasonable distance for comparison with those on the gathering ground of the Burrator Waterworks was at Altarnon in Cornwall, and, adjusting the rainfall for the seven years with that given by the Cornish gauge for the 35 years, 1866 to 1900, it would make the record of the six gauges for the seven years come to 54¾ inches for these 35 years. The only gauges on Dartmoor which gave a greater rainfall than that were just over the watershed of the Plym, in the Cowsic Valley near Princetown. There were two gauges there which gave a record of something like 75 inches, but they should not be taken into account at all. It was very well known that most of the rain came from the S.W., and it was a curious thing that the heaviest rainfall on Dartmoor—and it was also the case in other districts in the south of England—was just over the highest land, that was on the leeward and not the windward side of it. So it would be found that N.E. of the district shown on the plan, in the Cowsic Valley, which drained into the Dart, there was a heavier rainfall than in the area which was the gathering ground for the Burrator Waterworks. The people of Plymouth might be congratulated upon the fact that while the rainfall in Plymouth was not more than 37 inches per annum, they had within a convenient distance a considerably greater fall. The rainfall in the winter was moreover here 8 inches more than in the summer, which was decidedly advantageous for a water-supply. London was not nearly so well off, for the gathering ground for its water-supply had very little greater rainfall than London itself, and there was about an equal fall in summer and winter.

President. The PRESIDENT said his connection with the work described had been an exceedingly pleasant one, and, with the Author in charge of it, his duties had been almost a sinecure. Mr. Sandeman had prepared all the working drawings, which had received very little alteration or correction in his office. His principal function had been to give the Author some hints about construction when on the ground. The trench at Sheepstor had been one of the most irritating and annoying things he ever had to do with. To have to sink a trench 105 feet deep for an earthen dam standing only 22 feet above the ground was certainly a most tantalising

[1] Minutes of Proceedings Inst. C.E., vol. cix. p. 89.

proceeding. Time after time when he had gone down to visit the work during its later stages he had expected to find that the Author had bottomed the trench, but only found that another dry rubble wall had been discovered in the middle of the rock, through which the water was passing. The Author had mentioned in the Paper a splendid piece of diplomacy on the part of Admiral Drake, who had been engineer for the earlier scheme—namely that, when opposition arose, he had made himself Chairman of the Committee which had to decide on its merits. He would often very much like to be able to put himself in that position when serious fighting was going on in the Committee rooms. The President.

The Author, in reply, referring to Mr. Hill's question as to why the culvert was filled up solid around the discharge pipes, remarked that it seemed to him more satisfactory to know that the dam was equally strong throughout; and it was open to question whether it was not more reasonable for him to ask why should the culvert not be filled up? There was no danger of a burst pipe, and should the pipes in course of time wear away by corrosion, no harm would be done as a culvert of concrete would be left. With regard to the surging of the water in the weir-pool, the only difficulty in measuring the discharge over the weir might be during a large flood. Only one such flood had occurred since the reservoir was filled, and unfortunately he had not seen it; but, according to the account given to him, the movement of the water in the pool had not been very unusual considering the stormy weather. The reservoir was not designed to deal with the whole yield of the watershed, but it was estimated that in conjunction with the dry-weather flow of the stream it would yield about $8\frac{3}{4}$ million gallons per day. Regarding Mr. Marsh's observations, he might say that the flood which occasioned a head of 5 feet on the culvert had not been the greatest known flood, but the largest observed during the construction of the works. The moorland water had considerable effect on both cast-iron and steel pipes. In the latter case manholes were provided for allowing entrance to the pipes to remove corrosion. The covering to the water-face of the Sheepstor embankment was rough granite pitching. In reply to Mr. Hopkinson, one of the rain-gauges on the watershed had been observed for 30 years. That gauge gave an average of 58 inches. In regard to some of the others, it was necessary to make allowances for their position. The two gauges referred to—at Princetown—gave, as Mr. Hopkinson had said, very high records, but they had not been used in calculating the rainfall on the watershed. The Author.

Correspondence.

Mr. Cornish. Mr. J. E. CORNISH considered that the Paper offered several points of interest, one of them being the difficulties encountered in the foundations owing to the presence of decomposed granite. The circumstances under which this had been dealt with formed an interesting comparison with the work of the large dam now being built across the Nile at Assuan, where, it appeared, decomposed granite had also been met with. The arrangement of tilting floors for the cement shed appeared to be an ingenious contrivance. He would like to ask whether it had given good results, and whether there might not be some danger that in falling vertically from one floor to another the heavier particles of cement might become separated from the lighter. The materials used for the concrete seemed to have been excellent, but as in similar works there had been so much difference of opinion as to the state of dryness or wetness in which concrete should be used and the extent to which it should be rammed, some reference to these points would have been useful. With regard to the screen-chamber, much difficulty had been experienced in many cases in the working of such very fine screens as those used with gauze meshes of 1,600 to the square inch. It would be very interesting to know how the gauze was backed, and whether the method used was successful in preventing the tearing of so fine a mesh. With reference to the 25-inch pipe line, there was no information as to the diameter of the sluice valves fixed at every ½ mile. Modern practice tended to show the advantage of making such valves of a smaller diameter than the pipe, and that the loss of head which resulted from such change of diameter was exceedingly small. Examination of many old water pipes, which had been exposed to view or had had to be moved in London about 40 years ago in connection with the London main drainage and underground railways, had led him to believe that the determining factor in the life of a cast-iron main was generally corrosion from the outside, and if such was the case it would seem to be of questionable advantage to make any considerable reduction in the thickness of a cast-iron pipe on account of the decrease of internal pressure, or to use on a permanent pipe line a portion of steel pipe of so small a thickness as ½ inch. Laying such pipes to gradients involved two inconveniences, 1st, extra cost, 2nd, a much greater probability that the pipes did not

rest on solid ground; and provided that care were taken that the pipes should incline as much as possible in the same direction, he believed that some small deviation from a rigid straight line was of decided advantage in distributing the effects of expansion and contraction more evenly over the length of the main, and with the same object in view he believed that the best form of lead-caulked joint was better than the turned-and-bored joint, even when, as in the present case, a common socket was used at every sixth pipe. Mr. Cornish.

Dr. Boyd Dawkins remarked that the Paper touched on points which concerned the geologist and the engineer in almost equal degree. The geological section of the Sheepstor trench (Figs. 7, Plate 1) revealed a considerable and irregular thickness of decomposed granite, containing spheroids of undecomposed granite, and traversed by a network of quartz veins and veins of sheared granite. These veins had been traced down into the irregular surface of the solid granite forming the base of the puddle-trench. The decomposed granite, highly charged with water, was, as the Author suggested, the result of the attack of the carbonic acid in the rain-water on the felspar crystals, and to a less degree of the micas in the granite, leaving the third element of quartz untouched. The Author was right too in considering the spheroids to be the result of the decomposition having taken place from the lines of joint, which were lines of weakness, giving access to the water. In consequence of this, the rock would not be so decomposed in the spaces between the joints as in places where the water could not get so freely. In some cases the spheroids were formed of fresh unaltered granite. This, it might be remarked, had been the history of the granite tors, and all the rounded blocks, which formed so striking a feature in the granite district of Dartmoor. All had been formed in this manner, and they now occupied the surface because the softer materials had been removed by denudation. These softer materials had been deposited in the form of china clay (kaolin), and the micaceous sands associated with them, on the flanks of Dartmoor, at Bovey Tracey, and elsewhere. Dr. Dawkins

The quartz veins were not attacked by carbonic acid. The veins of sheared granite, some of which were decomposed, had been subsequently saturated, if the phrase might be used, with silica, derived, in all probability, from the decomposition of the felspars. Consequently, they constituted hard lines of division in the decomposed granite. It was likely, also, that the shearing was one of the causes of their hardness. The quartz crystals, in some of the drusy cavities, proved that these veins had been

Dawkins. traversed by water containing silica in solution. These interlacing veins would tend to form barriers, preventing the free passage of water through the decomposed mass, and would aid in storing up the rains of winter for the flow of the streams in the summer and autumn.

Water-bearing beds, formed by the decomposition of igneous rocks and crystalline schists, resting *in situ* on the fresh rocks below, occurred over a limited area in the British Isles—in Devon and Cornwall, and in the Channel Isles. In Guernsey they formed a cover from 30 feet to 40 feet thick, and were riddled by veins and volcanic dykes. They also in this island, as in the case in point, occupied irregular hollows in the fresh rock. As a result of these conditions, the water was stored in the porous, decomposed rock, in water-tight cells, like those of a honeycomb, though more irregular. Consequently, there was no free circulation, as there would be in a stratified water-bearing rock under ordinary circumstances. A well would only draw on its own reservoir, and be independent of adjacent wells, and there was no possibility of obtaining a large supply from any one centre of pumping, although there might be many wells, each sufficient for small local demands. These facts had come before his notice some years ago, in the course of an inquiry into the water-supply of Guernsey. They appeared to be of considerable practical importance in considering the question of water-supply where similar decomposed rocks lay *in situ*, and had not been transported by water.

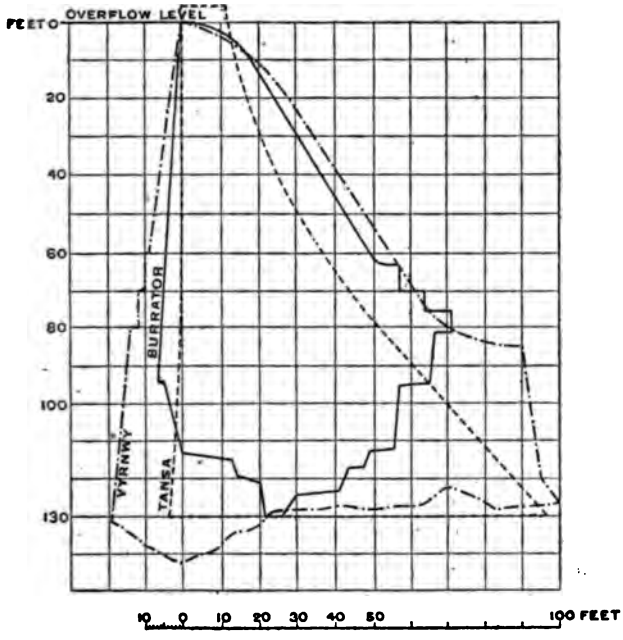
The reason why the area of these superficial accumulations was so restricted in Britain was, as he had already pointed out in his "James Forrest" Lecture[1] in 1898, the presence of large masses of ice in the glacial period, in the British area, north of a line passing through Bristol and London. There had been no glaciers south of this line to remove the superficial accumulations. To the north of it, in the granite of the Lake District, of Scotland, of the Isle of Man, or of Ireland, such accumulations as those described in this Paper would be looked for in vain. They had been removed from all these regions by the ice and had been distributed far and wide over the lower districts by the glaciers and the icebergs.

Mr. Dick. Mr. FRED. J. DICK thought it was interesting to compare the cross-section of the Burrator dam with both the Vyrnwy and the Tansa dams, taking the latter as raised to the full height originally intended. In the section of the Tansa dam given by Mr.

[1] Minutes of Proceedings Inst. C.E., vol. cxxxiv. p. 254.

G. F. Deacon[1] for comparison with Vyrnwy, the Tansa dam was shown at its reduced height as at that time completed. *Fig. 8* showed the comparison suggested, and it would be seen that while the Burrator dam approximated to the Tansa dam on the inner face, there was still a considerable difference on the outer one between Burrator and Tansa at depths from about 30 feet to 80 feet below overflow-level, apart from the projection designed to deflect the water horizontally. He thought, however, that it would be generally admitted that, if there was any error in the Mr. Dick.

Fig. 8.

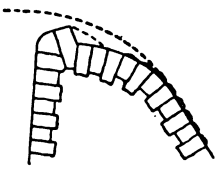


design, the Burrator dam certainly erred in the right direction; and having regard to the observations made by Sir Benjamin Baker in the discussion referred to, it was doubtful if engineers would be bold enough to adopt designs like that of the Tansa dam for straight dams with heights of 100 feet and upwards, especially when Water Committees had to be satisfied of the safety of the proposed structures. It occurred to him that the element of velocity of approach might interfere to some extent

[1] Minutes of Proceedings Inst. C.E., vol. cxv. p. 113.

Mr. Dick. with the correct estimation of heavy floods over the 50-foot gauge-weir, and as weir-discharges were best measured at an outlet from still water, it might be worth while considering whether reservoir-overflows, either on the crest of masonry dams or adjacent to earthwork embankments, should not preferably be designed somewhat as indicated in *Fig. 9*, combining a practically sharp edge which would nevertheless not arrest floating objects, with a drop sufficient to keep the weir from being backwatered even in heavy floods. The clock-work registration of overflow levels would then render possible a very close approximation by calculation to the actual discharge.

Fig. 9.



r. Friend. Mr. C. A. FRIEND agreed entirely with the Author as to the necessity of by-passes where sluice-valves of large diameter discharged into a main, and also as to the advantage derived, both in charging and working the main from laying it to gradients on account of the facility with which the air escaped; the additional cost was almost all in trenching. Unless the ground was treacherous, the inconvenience of laying every sixth pipe with a common socket seemed unwarranted by experience, the practice of setting out the main in straight lines and curves of large radius was to be advocated, the pipes in the curves being of the ordinary socket type, run with lead. The yield of 1·09 cubic foot of water per second per 1,000 acres was exceedingly high. At Algeciras, opposite Gibraltar, the dry-weather flow was 18 litres per second from a watershed of 1,400 hectares, which was approximately equal to only 0·18 cubic foot per second per 1,000 acres, the average rainfall being 35 inches; that was to say, just two-sevenths of the minimum flow of the area which supplied the Burrator works with about 60 per cent. of the rainfall.

Mr. Hill. Mr. A. E. B. HILL thought the method of construction, adopted in the Burrator dam, of rough blocks of stone bedded in a matrix of strong concrete, was admirable, and reached the limit of combined economy and efficiency. He had seen a large dam, about 175 feet high, constructed wholly of concrete; it was a magnificent structure, but he could see neither economy nor any other sanction for first crushing large rock small, and then cementing it together again in the construction of works of this massive character. If rock was available in large blocks, their incorporation uncrushed in such work seemed to be dictated by every consideration. The conditions at the Burrator dam, where the structure was underlaid and flanked by solid granite, appeared to lend themselves admirably

to the construction of a waste overflow-channel around the end of the dam, instead of passing waste water over the crest, and to the laying of the outflow pipes in a tunnel or channel under the dam, instead of in a culvert through it. A statement of the consideration, whether of economy or otherwise, which had induced the designing and consulting engineers to reject such methods, which must have suggested themselves, in favour of those adopted, would be of much interest. He did not gather with certainty from the Author's description or drawings, whether it was the bottom, or the water-surface level of the screen chamber, which was placed at 53 feet below top water-level. He would like to know the level, relatively to top water-level, of the crest of the weir over which the water passed on leaving the screen-chamber before entering the supply-pipe; and he would be very glad to have some further details of the construction and operation of this part of the work. With the full head of 161 feet on a 25-inch pipe from the Burrator to the Roborough Reservoir, $4\frac{3}{4}$ miles, he computed a delivery of 12,180,000 gallons per day might be counted on; while with 53 feet less head, or that due to the understood water-level of the screen-chamber, he computed a delivery of 9,976,000 gallons per day. He would like to know whether the delivery capacity of the 25-inch pipe had been given by the Author, as the result of a computation or as the result of an actual weir-measurement of its discharge. Where it was possible, in locating a pipe-line, to choose ground which presented, in profile, a series of large undulations, he held strongly to the view that it was possible, and most desirable, to dispense with stop-valves on the pipe except at the inlet and outlet ends. He had so located and designed a 14-mile line of steel main in 1892, and the result of its operation had been to fully confirm the views which had led him to do so. When repairs were necessary the valve at the head was closed. Any of the depressions in the pipe might then be discharged by its own blow-off valve, without letting off the whole contents of the pipe. Each summit in fact acted automatically as a gate. The refilling of the pipe was thus more quickly effected, and all was done without involving any of the dangerous shocks which attend the closing of stop-valves on a large main. He fully concurred in the Author's view that the labour and cost involved in laying pipes true to gradient was well repaid. He deemed it to be more than repaid in the assured efficiency and life of the pipe. A departure from the prescribed gradient, on a flat gradient, might permit an accumulation of air at some uncontemplated point. Such an accumulation meant two things. It meant obstruction to

Mr. Hill.

Mr. Hill. flow and diminished discharge, and it meant rapid corrosion and destruction of the pipe. He had had occasion, in laying steel pipes, to require a contractor to remove from the trench 1,500 feet of pipe put down in careless fashion, and reduce the trench bottom correctly to gradient; and thereafter he had had an assistant posted with level and rod to test every joint of pipes laid on flat gradients, and to insist on every joint being brought within ½ inch of its proper level. The results had fully justified in operation what many had regarded at the time as an unnecessary and burdensome exaction.

Lackland. Mr. J. J. LACKLAND remarked that it was stated in the Paper that where the 25-inch pipe crossed the Great Western Railway, for some distance the pipes were of riveted steel plates with flanged joints, and that the joints had been made by casting a ring of lead between the flanges, which were placed ½ inch apart. As this device for making the joints appeared to be more or less of a make-shift character, he thought it would be interesting if the Author could give information as to his experience with the joints in actual work; for instance, in the case of a leaking joint being repaired, if such necessity should have arisen, had any peculiar difficulty been encountered in reinstating the joint; and in the original making of the lead joints had any difficulty been encountered in preventing the molten lead from reaching the interior of the pipe, and, if so, how had this difficulty been overcome? The Author did not state whether the flanges in these pipes had been properly faced in the lathe, or whether they had been used without being machined.

Middleton. Mr. R. E. MIDDLETON observed that the deficiency of available information on the important subject of the capacity of drainage areas for supply seemed to him to be deplorable, and almost unintelligible considering the opportunities which engineers in charge of waterworks had for obtaining reliable data. On a few occasions in recent years he had had facts brought to his notice which had been calculated to upset the usual bases of calculation; and few as they had been he had considered them of so much importance that he had endeavoured to get further reliable data to confirm or confute the figures before him, and had written to several waterworks engineers asking them if they could supply him with information as to the product of the drainage areas under their control—his object being to tabulate the data he obtained for the benefit of the Institution. He was sorry to say that he had failed signally to obtain any reliable information, and he might say to secure any information at all. He begged waterworks authorities gene-

rally, and waterworks engineers in particular, to consider how important to the well-being of the country at large was an accurate knowledge of the rainfall and the comparative yield from drainage areas in different districts; and he asked them to put themselves in a position to ascertain with accuracy what was the rainfall in the district of each, and what was the amount of the yield from the same area measured in inches of rainfall, and to publish the information secured. Mr. Middleton.

Mr. R. Schröder, of Hamburg, remarked that the only thing he missed in the Paper was a statement of results of bacterial examination of the water impounded and supplied. Water coming from such sources as that in the Burrator Reservoir, and surface-water in general, might be clear and pure, but still would not always answer to modern hygienic demands from a bacteriological point of view. He thought it would be necessary to filter the water before its distribution, as was done by the Liverpool Corporation Waterworks at Oswestry with the water on its way from Lake Vyrnwy to Liverpool. Mr. Schröder.

The Author, in reply, remarked, with reference to Mr. Cornish's question regarding the working of the tilting floors of the cement shed, that he was satisfied with the result. One of the objects aimed at in designing this arrangement had been to remove the cement from one floor to another in such a way that the workmen employed were outside the cement shed, and were not inconvenienced by the flying cement. The screens had given some trouble, and he believed the introduction of a stronger and larger meshed screen was contemplated. His experience did not agree with Mr. Cornish's regarding the determining factor of the life of a cast-iron pipe where moorland waters were concerned, as the corrosion was greater from the inside than the outside. No doubt with harder waters the case was different. Dr. Boyd Dawkins's remarks on the decomposed granite were most interesting. He had referred to the way in which the winter rains were stored in the decomposed mass, and on this point the result of an experiment made to ascertain the quantity of water a cubic foot of decomposed granite would hold might be useful. He had been at a loss to account for the extraordinary dry-weather flow from the watershed, but eventually he had concluded that the water must be stored in the large areas of decomposed granite, and to support this theory he caused an experiment to be made which showed that 1 cubic foot of decomposed granite would absorb 18 lbs. of water. Referring to the remarks of Mr. A. E. B. Hill, the narrowness of the valley at the site of the dam had partially induced him to deal The Author.

The Author. with the flood water by passing it over the crest. The water-surface level of the screen-chamber was 53 feet below the top water-level of the reservoir. The quantities given as the delivery of the 25-inch main were not both actually measured. The lower figure was a measured quantity, but the higher delivery was a calculated one. It was impossible to obtain an actual delivery with the full head of the reservoir whilst the main was new, as the reservoir was not finished until between 4 years and 5 years after the main was laid, and in that time, with a soft water, nodules were formed in the pipe, and the delivery was impaired. The method of jointing the steel pipes had proved most satisfactory. He had had no experience of repairing the joints, as there had been no repairs to make. In running the joint, an iron ring had been placed in the interior of the pipe, to prevent the escape of the lead. The flanges of the pipes were faced.

16 April, 1901.

JAMES MANSERGH, President,

in the Chair.

(*Paper No. 3289.*)

"Modern Practice in the Manufacture and Distribution of Gas."

By HARRY EDWARD JONES, M. Inst. C.E.

HAVING presented to the Institution, in 1875[1] and 1880,[2] Papers bearing on Gas Works Construction and on the Purification of Gas, the Author is of opinion that, as the production and supply of coal-gas fulfils an extensive and profitable municipal service, 38 per cent. of the total quantity manufactured in this country being produced by works already in the hands of local authorities, the subject is entitled to some further consideration in a year when the President's chair is occupied by one whose distinguished career has been chiefly spent in connection with works for the benefit of great municipalities.

INTRODUCTION.

The closing years of the past century have been especially marked by three very important and far-reaching innovations in respect of the consumption of gas, the full significance of which has hardly yet been realised, nor has their prospective influence been fully estimated. These are:—(1) the Welsbach Burner; (2) the Coin-Meter; and (3) Sliding-Scale Legislation.

The Welsbach Burner.—This, the invention of Dr. Auer von Welsbach, consists of an incandescent mantle heated to radiance by various modifications of the well-known Bunsen burner, of which at the moment the best-recognised is that known as the

[1] Minutes of Proceedings Inst. C.E., vol. xl. p. 2.

[2] *Ibid*, vol. lxi. p. 1.

"Kern" burner. The introduction of this device has in an extraordinary degree assisted in the progress of lighting by gas, which is still its most important, though not, as formerly, its sole duty. By magnifying the normal illuminating power of the gas five-fold, it reduces the consumption and cost in an equal ratio; necessarily therefore removing the larger part of the products of combustion for the same amount of light. The invention came at a time when the public mind was stimulated to look for great developments in electric lighting, with a corresponding displacement of gas lighting. Especially has it assisted gas in the competition for street lighting; because, although other forms of burner were capable of giving light equal to that of the incandescent electric lamp, the position of gas was entirely different with respect to the large electric arc-lights, which were formerly unrivalled in intense lighting-power, though their cost prohibited their use except in important streets and areas.

Although the late Sir Edward Frankland demonstrated long ago the high illuminating value of coal-gas if burned at a high temperature, which in his experiment was obtained by electric heating and ignition, little advance had been made beyond the Siemens regenerative gas-burner (which was soon copied and modified by other makers) until Welsbach gave to the gas industry a burner which has armed it against all competition for in-door or out-door illumination, wherever comparative cost is regarded. This statement is made without limitation, because by compression and heating of the gas, and by grouping the burners in clusters, illuminating powers can be obtained which rival the electric arc, at a relatively insignificant cost. On the other hand, the ordinary mantle-burner, developing between 40 and 50 candle-power from a consumption of 3 cubic feet of gas per hour, suffices for lighting ordinary streets uniformly and effectively. Moreover the use of a larger number of separate lamps of lower individual power, thus dividing and distributing the total illumination, affords the most effective and economical system of lighting. This must be obvious when the loss of light by radiation is considered, for if one light is to take the place of four in line its power must be increased sixteen-fold; and with this loss are coupled the disadvantages of undue illumination in the immediate neighbourhood of the lamp, and comparative gloom in the middle distance.

The Coin-Meter.—The second of the important innovations referred to is the adoption of the use of gas for lighting by large

numbers of the working-classes, who, since the introduction of the coin-meter, have called for gas-supply by that means in such numbers as to overwhelm the suppliers by the demand for the necessary fittings within the houses, the cost of which on this system is included in the charge for the gas. By bringing greater comfort, convenience, and safety into the dwellings of the working-classes, this system conforms with modern municipal aims, and by securing the adhesion of the masses of the people it has largely helped to consolidate the position of gas-supply.

The addition to the number of consumers brought about in this way in the 10 years ending 1899 has been especially large in the cases of the Wandsworth and Putney Gas Company, 223 per cent.; the South Metropolitan Gas Company, 165 per cent.; and the Crystal Palace Gas Company, 119 per cent.; while many other gas-companies have similarly experienced a large increase in the number of consumers.

The Sliding-Scale Legislation.—By raising the dividend as the price of gas falls, the sliding scale has urged to cheaper methods of production, greater attention to residual products, more careful expenditure of capital, and efforts towards popularizing the use of gas by the introduction of suitable appliances on terms which enable consumers to employ them without incurring capital expenditure; and further, it has led to special concessions and reductions in the price of gas to large consumers for trade purposes.

That the growth of gas-supply has been greatly affected by these three causes may be seen from a comparison of the statistics given in the Board-of-Trade returns. The volume of trade has increased by 21¾ per cent. in the past 4 years; and if this figure is not particularly striking as a simple ratio, it must be remembered that it is calculated upon a basis already so large, as compared with any analogous industry, that the increase shown, whether considered in money value or in volume of production, is far in excess of what has accrued to any competitive system. In this connection it may be observed that, according to Garcke's return,[1] the electric-lighting industry in 1899 had a capital of £23,279,347 compared with £99,046,880 for gas-lighting, or 23½ per cent.; while if 4 watts per hour be required for 1 candle-power and 3 candles per foot per hour be taken as the illuminating value of the gas by ordinary burners, then the electric output is equal to 31,279 million candle-hours against the gas output equal to 407,165 million candle-hours, or only 7·7 per cent.

[1] Garcke, "Manual of Electrical Undertakings."

GAS UNDERTAKINGS, BOARD-OF-TRADE RETURNS.

—	Year ending December, 1895.	Year ending December, 1899.	Increase in 4 years.	Increase Per Cent.
Total number of undertakings .	632	682	50	7·9
Capital[1] . . .	£70,819,000	£99,046,880	£28,227,880	39·8
Receipts . . .	£19,461,000	£23,562,789	£4,101,789	21·0
Gas sold . . .	111,443,702,000 cubic feet	135,721,696,000 cubic feet	24,277,994,000 cubic feet	21·7
Miles of mains .	23,857	26,807	2,950	12·3
Number of consumers . . .	2,659,771	3,485,557	825,786	31·0
Public lamps . .	526,888	581,206	54,318	10·3

ELECTRIC LIGHT UNDERTAKINGS, YEAR 1899.[2]

Number	239
Capital	£23,279,347
Receipts	£2,041,695
Expenses	£1,136,230
Profit	£905,465
Units sold	125,116,615

These important factors have brought about a gradual and steady reduction in the selling-price of gas, which has further promoted its use for power and for a variety of trade purposes on all scales, as well as for domestic cooking and heating, which have lately been stimulated by the high price of coal. The great advantage of this class of consumption is that it reduces the cost of production, because it employs during the hours of daylight the plant and mains which would otherwise be idle; and further, it does not call for storage, thus saving capital- and maintenance-charges. It also reduces fixed charges, management, etc., and part of the labour and supervision per unit. A contingent advantage is that it raises the consumption of gas in the summer-time when the long working-days are available—a period when formerly the plant of a gas-company was employed to the extent of little more than 25 per cent. of its capacity. Thus by equalizing the summer and winter consumption, and so increasing the gross annual output, without increasing the capital- or working-expenses

[1] Much of this increase is nominal. The Gas Light and Coke Company converted its 10 per cent. stock into two and a half times the amount of 4 per cent. stock, and the South Metropolitan Gas Company did the same. The total nominal addition for these two companies is over £13,000,000.

[2] e, "Manual of Electrical Undertakings."

in the same degree, the cost of the whole supply is reduced, to the benefit of all consumers. This effect is illustrated by the experience of a Metropolitan company in whose district the daily consumption between 6 A.M. and 6 P.M., during the month of July, has been quadrupled in 12 years.

Labour-Saving Machines.

Among the methods of cheaper production, the need for which has been referred to as an indirect consequence of the sliding scale, labour-saving machines have been extensively adopted. The most important of these appliances are:—1. Automatic grabbing-cranes for discharging and handling coal and coke; 2. Retort-house machinery, actuated by steam, hydraulic power, compressed air, or wire-rope connections; 3. Conveying machinery for coal and coke; 4. Crushing and sifting machinery for coal and coke; 5. Inclined retorts, which receive coal and discharge coke by gravitation; 6. Machinery for filling and discharging purifiers. All these tend to better results by dealing with heavier weights than is possible in manual operations, and by preventing the defects, variations and consequent losses inseparable therefrom. Such apparatus can be introduced with safety and real economy only in works of adequate size, and many of the machines have hitherto failed to attain the speed and efficiency of zealous and well-directed hand-labour. Moreover, the coke from machine-worked retorts is worth less than that from the manual system, by 1*s.* 6*d.* to 2*s.* 6*d.* per ton, while it is much softer and loses more by storage.

Residuals.

The second element in the cheapening of production is the improvement in the return from residuals which has been secured in recent years, by the saving of coke used as fuel; by more completely separating the ammonia and manufacturing it on better lines at the gasworks, instead of transporting it in its bulky liquid form to manufactories at a distance; and by the separation of cyanogen, which is of great value in gold-mining. Again, further discoveries have added to the by-products of tar various colours and antiseptics and an extensive group of solvents, varnishes, timber-preservatives, lubricants and fuels, all of which are obtained by inexpensive processes and are cheaply produced in consequence of the large amount of tar put on the market.

Breeze (small coke and ashes) is much used for making, with Portland cement, a light artificial stone, and in improved furnaces can be used as fuel for steam-boilers.

Graphite scale from the retorts is of value for electric-arc carbons, the price varying between £4 10*s.* and £5 per ton.

Naphthalene, which when deposited in the distributing-pipes presents so serious a difficulty, is of considerable value as albocarbon, used for enriching gaslight, and also yields an additional group of colours. It is further used as a dry and cleanly antiseptic and preservative of fabrics from moths, &c.

Even the refuse purifying-materials are now being turned to account, spent oxide of iron yielding sulphuric acid, ammonia, and Prussian blue; and spent lime being reburnt into caustic lime. Such refuse as the clinker from the furnaces and old broken retort-material has a saleable value in most populous places for concrete and road-making.

It will thus be seen that of the materials imported into gas-works, even the impurities and refuse are turned to useful account. Indeed a striking difference between gas-making and all other uses of coal is the large value realised by sale of the residuals after providing for the requirements incidental to the manufacture. The yield from 1 ton of good Durham coal is:—

	Cwt.	Lbs.
Gas (15 candles)	8	25
Ammonia	0	6·4
Coke	12	45
Breeze	1	70
Tar (10 gallons)	1	1
Water (12 gallons)	1	8
Impurities	0	36·3
Cyanogen	0	1·5
Total	19	81·2
Difference—probably represented by gas lost in retort and elsewhere, and graphite deposited	0	30·8
	20	0

While dealing with these points it is important to follow the reaction, upon the price of coal, of the increased use of gas for fuel, which, while forcing upon gas-manufacturers the production of a larger quantity of coke, on the other hand curtails to that extent the outlet for it by diminishing its applications. This causes powerful competition with coal and tends to reduce its price. Bearing in mind that, for every ton of coal carbonized, at least

half a ton of coke is forced upon the market (after allowing for the fuel necessary for carbonization), and that, except by maintaining the balance between supply and demand, there is no means of controlling the price of this coke—which is produced whether saleable or not, has to be sacrificed at any price when accumulated to an inconvenient extent, and suffers an inevitable loss of weight and bulk by storage—it must be recognised that here is a very powerful check against any undue enhancement of the price of coal. The 13 million tons of coal carbonized in gas-making in the year 1899 was not entirely destroyed, 6½ million tons, roughly, of good coke fuel being put back on the market, with more than 700,000 tons of tar, which may also be regarded as a fuel, inasmuch as its product, pitch, is largely used for artificial fuel, and it can itself be used as liquid fuel. This output of coke was forced by the demand for the gas; it could not be restricted, nor could the market price of the coke be controlled; so that it safeguarded, as far as it went, the interest of the general user of fuel.

Enrichment of Gas.

The enrichment of the gas largely affects the return from residuals, by reducing the coke available for sale, inasmuch as no enriching material, not even cannel (with unimportant exceptions), yields coke. Cannel costs twice to three times as much as coal, and yields 4 cwt. or 5 cwt. of worthless ashes, compared with 12 cwt. to 13 cwt. of coke, while it requires more fuel to carbonize it. When, therefore, an illuminating power is required beyond that afforded by the coal from the neighbourhood of the gasworks, the cost of enrichment inevitably exceeds its relative value to the consumer, even with the ordinary forms of burner; whilst with the Welsbach mantle-burner it may be said to be absolutely wasted.

The saving effected where enrichment is not required is shown in the Table, p. 50. The individual gasworks in London and suburbs mentioned in this Table are those which do not use or need much enrichment. The grouped undertakings of provincial corporations and companies are those which are compelled by standard illuminating power or by standard burners to use a good deal of enrichment, which in the case of Dublin is wasted, because the standard burner used there, like the burners employed generally by the consumers, cannot burn the gas properly. The differences represent several pence per 1,000 cubic feet in cost, in favour of the enriched gas.

RETURN BY SALE OF RESIDUALS, PER CENT. OF COST OF COAL AND ENRICHING MATERIAL. (From *Field*.[1])

Year.	First Group.		Second Group.			Third Group.		Fourth Group.	
	Metropolitan Companies.	South Metropolitan Company.	Suburban.	Wandsworth Company.	Croydon Company.	Provincial Corporations.	Glasgow.	Provincial Companies.	Dublin.
Illuminating Power.	16 Candles.	16 Candles.	14 to 16 Candles.	14 Candles.	14 Candles.	14 to 18 Candles.	20 Candles.	14 to 16 Candles.	16 Candles nominally, but Burner bad.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1896	60	66	51	61	60	44	47	50	44
1897	53	58	44	55	55	44	44	50	37
1898	60	65	50	70	60	45	42	59	39
1899	67	75	55	74	64	50	42	67	43

[1] "An Analysis of the Accounts of the Principal Gas Undertakings in England, Scotland and Ireland."

Carburetted Water-Gas.—This affords a convenient, cheap, and effective means of giving a permanent additional illuminating-power. The cost will always be largely affected by local conditions; but for works on the Thames at recent current market values for oil and coke, with the "Lowe" plant as arranged by Messrs. Humphreys and Glasgow, the cost is given, in the second Table below, for 20-candle gas, at 18·19*d.* per 1,000 cubic feet; the first Table showing the cost of 14½-candle gas from Durham coal, viz., 16·98*d.* per 1,000 cubic feet. The difference is 1·21*d.* per 1,000 cubic feet.

COAL-GAS, JUNE 1900.

(Cost into the gasholder per 1,000 cubic feet.)

	d.	*d.*
Coal	..	19·29
Coke, realised	7·89	
Breeze „	0·47	
Tar „	1·87	
Sulphate „	2·12	
Total residuals realised	..	12·35
Net cost of coal	..	6·94
Purification	1·09	
Wages and salaries	4·59	
Wear and tear	4·36	
Total working-expenses	..	10·04
Total cost	..	16·98

OIL-GAS, JUNE 1900.

(Cost into the gasholder per 1,000 cubic feet.)

Materials—	*d.*
Oil, at 3·16*d.* per gallon	10·43
Water	..
Coke, at 15*s.* 10*d.* per ton	4·05
Total	14·49
Less tar, at 1·82*d.* per gallon	0·79
Net	13·70
Purifying and labour	2·03
Wages and salaries	1·91
Wear and tear	0·54
Total cost	18·19
Quantity of gas made	478,222,000 cubic feet.
„ „ „ per gallon of oil used	302 cubic feet.
„ tar „ „ „ „	0·115 gallon.
Coke used per 1,000 cubic feet	47·9 lbs.

The cost of purification of carburetted water-gas is here exceptionally high, owing to special local difficulties with regard to the disposal of spent lime, and also to a temporary enhancement in the price of lime in the winters of 1899 and 1900. The wear and tear is given at only the actual outlay on a comparatively new plant. The Author believes that so far, in this country, the plants have not been worked long enough to afford reliable data for ascertaining the cost of renewals, and it may prove that an addition of ½*d.* to 1*d.* per thousand cubic feet should be invested annually to provide a sinking fund for renewal.

A number of collateral advantages are incidental to the system, among which may be mentioned :—

1. Facility for quickly varying or suspending the output of gas is obtained without, on the one hand, providing beforehand for storage of bulky raw material and for many additional workmen; or, on the other hand, suffering material loss or damage by suspension. This adaptability conveniently meets sudden climatic changes and powerfully supplements the storage-plant, so that, in several cases of delay in the provision of additional gasholders, loss of trade and inconvenience to consumers have been effectually obviated.

2. Complete control is afforded over the illuminating power, which can instantly be increased by nearly 50 per cent., at a cost much below that of gas from cannel coal.

3. The capital cost of the plant, up to the purifiers, is much less than for coal-gas, while the buildings and the area of land required are many times smaller. Thus a plant for 1¾ million cubic feet per day covers ¾ acre, and costs £17,000, while the corresponding retorts, coal-stores, condensers, scrubbers, engines, exhausters, boilers and coke-storage could not be furnished for less than £58,000, nor on a less area than 4 acres.

The purifiers, however, have to be much larger—nearly twice as large—and the cost of purifying is much greater than for coal-gas, the impurities amounting to between 2,050 grains and 2,400 grains per 100 cubic feet (compared with 1,200 grains to 1,400 grains for coal-gas) and being such as to require mainly lime, which is more expensive. The specific gravity of oil-gas being higher—0·64 against 0·45—the connecting pipes to the gasholders and the distributing-mains should be larger, or else they must be worked under higher pressures.

4. There is less accumulation of coke in winter, when the stocks rise and values fall, and as the process both consumes coke and displaces part of that which otherwise would be produced from coal plant, the gain is two-fold.

5. A less important benefit arises from the reduction of naphthalene by this gas. This has effectually kept clear mains which, especially under the Docks, were previously often badly blocked. A saving arises here in labour formerly employed for dealing with stoppages, which inflicted inconvenience, and sometimes loss, on consumers, while the sale of gas was correspondingly diminished.

6. Further, the storage of the oil requires less space than the storage of coal. Coal for 10,000 cubic feet of gas occupies 43 cubic feet; the corresponding quantity of oil occupies 4 cubic feet only.

As a means of relieving the stress of the maximum winter demand for coals, labour, and storage, for both gas and coke; of promptly producing large volumes of gas to meet sudden calls due to fogs and changes of temperature; and lastly, of reducing the expenditure on capital, maintenance, and renewals, water-gas plant may be considered a most valuable, convenient, and economical auxiliary to a gasworks. Where enrichment is necessary this plant is practically indispensable; but where good facilities exist for receiving coal from ships, or from railways communicating direct with the collieries, and especially where the standard of illuminating power is within the compass of common coal, then for the larger part of the year coal-gas plant must generally be the more economical. From the point of view of reducing capital outlay, it must be remembered that only 200 times the maximum daily supply can be reckoned on for the whole year, and that more than one-third of the whole plant must be idle for the greater part of the year. This involves capital tied up unproductively, but suffering depreciation by time, weather, etc. For the extra winter demand there is clearly a saving in this respect of the difference between the two estimates of capital cost given above, *i.e.*, between £17,000 and £58,000, say 70 per cent. To reduce capital expenditure, to save space, to give greater flexibility in the output, to avoid the mid-winter pressure on collieries, steamers, and railways, and to avoid glutting the coke-market, means not only saving in money, but less risk to the gasworks service; to say nothing of the relief from anxiety on the part of the staff.

Only in this way, it is believed, can this auxiliary plant be safely and economically applied, and the Author would deprecate any general rush to adopt the system, ignoring the evidence of recent experience that whenever coal is dear, oil, being a fuel, will follow; and although, if used in moderation, it will keep the coal market in check, if used to an extent beyond the ratio indi-

cated it may attain a price which, as at the present time, is nearly prohibitive.

In the year 1899 there was supplied by some forty gasworks a quantity of carburetted water-gas equal to between 20 per cent. and 60 per cent. of their total output. This experience is of great value as bearing on the safety of the use of water-gas, seeing that with incandescent-mantle burners suited to all scales and powers of lighting, there is no real necessity for enriching the water-gas, which could be produced in its crude state at a saving of, roundly, 1*s.* per 1,000 cubic feet, and would be for all purposes equally useful to the consumers, and even more valuable for heating-purposes.

In undertakings which are now supplying illuminating gas at a charge varying between 2*s.* 2*d.* and 2*s.* 8*d.* per 1,000 cubic feet, this saving would bring the rate down to between 1*s.* 2*d.* and 1*s.* 8*d.* per 1,000 cubic feet, which reduction could not fail to develop immensely the use of gas for power and heating.

Capital Expenditure in Gas Undertakings.

The importance of the various advantages arising from the foregoing improved methods and developments, in reducing the selling-price of gas and so increasing the consumption, cannot be disregarded. But it is in the limitation of capital expenditure that the greatest permanent saving is to be attained. It may almost be said that all the undertakings supplying cheap gas are those with relatively small capitals. This is plain from the consideration that the dividend and interest charge is seldom less than 9*d.* per 1,000 cubic feet, and often amounts to 1*s.* 6*d.*, and in some cases 2*s.* per 1,000 cubic feet. By reference to Mr. Field's admirable analysis of the accounts of the leading gas-undertakings in the United Kingdom for 1899, pp. 7–14, it may be seen that the charge under these heads varies between 7¼*d.* and 17*d.* per 1,000 cubic feet. Clearly there is room here to abate the selling-prices of gas by a considerable fraction of a shilling, while the economy to be effected by labour-saving appliances is limited to a penny or two per 1,000 cubic feet, discounted by an increased charge for the wear and tear on such appliances.

Where conditions are not too unfavourable, works, mains, meters, and working-capital can be provided for between £400 and £500 per million cubic feet, for an output of 50 million cubic feet per annum and upwards. On this the ordinary dividend of 5 per cent. would entail a charge of only £20 to £25 per million cubic feet

or between 4·8*d.* and 6*d.* per 1,000 cubic feet. Since 1875, Parliament has compelled gas-companies to raise their capital at the market rate of interest by selling the new stock by auction, and most of it has been so raised at little over £4 per cent. Where a higher charge exists, it must be accounted for either by the higher rates on the older capital (previously allowed 10 per cent., which raises the 4·8*d.* and 6*d.* to 9·6*d.* and 1*s.* respectively,) or else by the ruinous practice of keeping alive, in the accounts of the undertaking, capital which attaches to obsolete or even non-existing plant. For this there is no more excuse than for the opposite condition of things, which has been occasionally remedied by re-valuations, and has been recognised by Parliament allowing the addition of capital furnished from revenue, but safeguarded by the limitation of dividend to 5 per cent. No special or general Acts can be strained to cover so unsound a practice, which may be due to ignorance or to negligence in omitting to write off old plant, so that the capital account includes the cost of disused or useless or even non-existent plant, as well as of the actual revenue-earning plant. The enjoyment of a monopoly alone renders such mistaken action possible; but when fairly recognised, every effort of the engineer should be directed to countervail it, by making necessary extensions as far as possible at periods when moderate prices rule, by adopting inexpensive forms of construction, and by rigorously writing off displaced or disused plant and buildings. The gain by this practice could easily be illustrated from well-known instances, and everywhere the result has been a large reduction in the selling-price of gas, coupled with accumulations of surplus profit or higher dividends under sliding scales. It is clearly idle to strive for small economies by introducing expensive complications, while shutting out of sight the larger permanent burden resulting from an inflated and unwarranted capital account.

It is worth while to examine this subject of capital in some detail. Roughly two-thirds of the entire expenditure of fixed capital is incurred in the works for manufacture, under which head are included the plant for carbonizing, purifying, and storage, and for the treatment of residuals. The remaining one-third of the capital would be absorbed by the distributing-mains and services, and by meters and stoves; but the additional provision of house-fittings, stoves and meters, for small consumers on the coin-meter system, is tending to disturb the ratio, because in relation to the consumption of gas (usually 15,000 cubic feet to 20,000 cubic feet per house per annum) the outlay, varying

between £4 and £6 for each house, means an extra capital of 6*s.* per 1,000 cubic feet beyond the normal capital of say 10*s.* per 1,000 cubic feet, covering the whole of the plant, mains, &c.

Works of Manufacture.

Here the engineer has most scope for economical treatment in selecting and designing:—

1. A site for works, affording direct access for coal, by ship or railway, and for the delivery of residuals, and affording good foundations for the plant and structures.

2. Carbonizing and purifying plant arranged for saving labour and expense in moving material.

3. Gasholder-tanks and storage-tanks of the most suitable materials available.

4. Gasholders of which the dimensions and form are such that they are capable of extension by adding sections, so as to be permanently available on future expansion of trade.

5. A distributing system which avoids the laying out and use of service-mains of too small a diameter, and which has direct arterial lines, few in number and of such calibre as to delay for as long a period as possible the necessity for enlarging them.

The following appliances are now available for equipping works which are of sufficient size to employ them with advantage:—

1. Coal-grabbing cranes, which in unloading ships or barges save the difference between, say, 4*d.* and 1*d.*, *i.e.*, 3*d.*, per ton.

2. Siemens regenerative furnace for retorts, which saves one-fourth of the fuel otherwise necessary, and three-fourths of the labour of firing, whilst ensuring a higher and more uniform temperature, and consequently a larger output of gas per ton of coal and per retort, with longer life of the retorts and furnaces.

3. Mechanical appliances for charging and drawing the retorts by hydraulic power, compressed air, or steam, with direct-acting or wire-rope gearing. Such machines are fed with coal usually from overhead hoppers filled by elevators from crushing-mills below the ground-level, which are again supplied from the stores by conveyors or by trucks on rails or roadways (Fig. 1, Plate 2).

To avoid the cost of the fixed elevators and the overhead construction, and, further, to enable the coal to be taken direct from the stores to the retorts, saving removal to fixed points, followed by transfer to the machine, various systems have been devised. First,

that by Mr. George Livesey, M. Inst. C.E., for dredging the coal from the floor-level at the side of the stores into the charging-machine (A, Fig. 3, Plate 2). Second, that designed by the Author and used at the Wapping and Poplar Gas Works, where a hydraulic grabbing-crane feeds the machines from the coal-stores (B, Fig. 3, Plate 2). Third, a plan in use at the Poplar works, arranged by Mr. S. W. Ludbrook, Assoc. M. Inst. C.E., and the Author conjointly, for feeding the machines from single trucks on a light railway suspended from the roof (C, Fig. 3, Plate 2). This last involves the constant employment of a grabbing-crane outside the retort-house, either unloading barges or ships or taking from a convenient store; and though preferable in this instance, where the existing retort-house had to be adapted to the use of machinery, it is not considered so good as the second plan where the retort-house can be arranged for it.

The capital costs of the variations from the simple hand-charged and direct-fired retorts, suitable for small works (Fig. 4, Plate 2) are as follows for the south of England:—

	£.
Cost per single 10-foot direct-fired retort	22
With house and coal-store included	47
Do. on elevated floor for firing with gas-generators . . .	40
With house and coal-store	85
Do. as above with the Livesey or Jones feeding-machines .	45
With house and coal-store	95
Do. as above.	50
With the usual crushers, conveyors and overhead hoppers	100

Where very spacious and substantial buildings are employed the foregoing figures are largely exceeded.

The cost of carbonizing per 1,000 cubic feet with the fully machine-equipped retort is found to be 1·2*d.* as against 2·5*d.* by the ordinary hand-charging and drawing on ground-floor retort. An exceedingly cheap plan of semi-machine stoking is that designed by Mr. H. S. Freeman, Assoc. M. Inst. C.E., at the Wandsworth Gas Works, where the ordinary ground-floor retort-house and direct-fired retorts produce 7,000 cubic feet per diem, and the cost of carbonizing is only 1·5*d.* per 1,000 cubic feet (D, Fig. 4, Plate 2), the machinery costing only £500 for eighty-four retorts. A system asserted to be more suitable for smaller works than those to which the above can be economically applied, is that of inclined retorts (see Fig. 5, Plate 2). These cost £100 per retort, and the working cost per ton is put at 0·9*d.* per 1,000 cubic feet. This system labours under the undisputed drawback that at the angle of inclination suitable for easy discharge of the

coke, the coal, when highly bituminous, is liable to slip down the heated surface and to choke the lower end of the retort. When this happens the charge is imperfectly carbonized, and such gas as is produced is of low illuminating power. Alteration of the angle, to avoid this slipping or creeping, renders the retort unfit to deal with a less bituminous coal, which then clings to the retort, and, when coked, is discharged with difficulty. This objection, which is minimised by some and disputed by others, is, however, well recognised and must be absolutely overcome before the system can make much headway.

Purification-Plant.—Purifiers have long been constructed by the Author without hydraulic seals to the covers. These extend to the whole area of the purifiers, and are not mere man-lids, such as are used at Preston and at the Crystal Palace Gas Company's Works. The covers are not only held down and jointed by bolts round the edges, but are enabled to resist the pressure within the purifiers by long internal bolts equally spaced over the area and holding the cover to the floor of the purifier, so that the cover itself does not need to be heavy and consequently expensive. The various reactions have hitherto been accomplished in due sequence by multiplying the groups of purifiers, it being necessary to eliminate in consecutive order first the carbonic acid, second the bisulphide of carbon, and last the sulphuretted hydrogen, involving, therefore, three processes and three sets of purifiers, of three or four vessels each, or probably at least seven vessels working in sequence. To avoid the use of so many vessels the depth of the purifiers is increased, and both oxide of iron and lime are used in each, while the number in the single group employed is raised from four to five. This dispenses with the two additional groups which have hitherto been necessary. Owing to the difficulty of maintaining the absolute gas-tight condition of large slide-valves, water-sealed valves are now used exclusively in the Author's practice. Fig. 6, Plate 2, shows such purifiers equipped with cranes for charging them; the cranes run upon lines of rails flanking the vessels on either side. Preferably the vessels are arranged over a lower floor or cellar, into which they are discharged by gravitation with despatch and economy of labour. It will be seen that a large saving in metal and in space is secured by dispensing with water-seals to the covers, in separating adjoining vessels by one plate only, thus saving four complete sides in five vessels; by connecting the pipes to the sides of the vessels at different levels for inlets and outlets; and by using water-sealed valves, which also act as siphons.

For efficient action on the impurities, the required temperature must be maintained in purifiers, and if they are not placed in suitable buildings they must be warmed by passing steam with the gas, or by other artificial means, without which the sulphur purification will fail in very cold weather. Centre valves, though convenient, inevitably cause stains of sulphuretted hydrogen for some time after being moved to change vessels, and also by reason of their containing condensed foul liquor in the receiver common to all the valve-chambers.

The cost of the system illustrated in Fig. 6, Plate 2, is :—

	£.
Set of five purifiers, 36 feet × 28 feet × 7 feet, capable of purifying 2,000,000 cubic feet per diem from all impurities, and dispensing with check purifier	5,000
House, and hydraulic lift connecting floors . .	4,157
	9,157

Together equal to £23 per million cubic feet of annual output.

With regard to condensation, the Author retains the preference he expressed in his former Papers presented to the Institution, for horizontal tubes in which the gas is cooled in contact with the tar and ammoniacal liquor. This is not only the cheapest form, but it is the only one which effects the separation of naphthalene. While it is true that in removing the naphthalene a certain percentage of light-giving hydro-carbons is also removed from the gas, the balance of advantage is believed to remain with this method of condensation.

In plant for removing ammonia by scrubbing or washing, the Author's preference is still for the original coke scrubber. For 26 years past, working under most rigid testing for ammonia by the Metropolitan Board of Works and the London County Council, exceedingly low returns have been made throughout by the testing-officers, comparing very favourably indeed with other undertakings working side by side, and the large return from ammonia sold confirms the good action of this plant.

The purification of gas, curiously enough, is essentially linked with the separation and production of the residuals. Coke, the chief residual, is almost universally used for scrubbing or washing the gas with water, and so removing ammonia, and consequently sulphur and carbonic acid, and in the Author's experience it is the best medium for this purpose. Tar, when condensed from the gas in a suitable form of condenser, will remove the naphthalene completely with only a small sacrifice of illuminating-power.

This statement may be questioned, but 25 years' experience at a works so fitted up, using concurrently the same coal as was used throughout by a London gasworks, enables the Author to speak with certainty on the point. Ammoniacal liquor removes a large part of both the sulphuretted hydrogen and the carbonic acid, and is capable, by re-distillation into caustic ammonia, of removing the whole of these impurities. But the treatment of ammoniacal liquor for this purpose is both complicated and expensive, and is liable to considerable waste; so that, although it would accomplish this work in closed vessels by the simple operation of pumps, and thereby realise a long-desired facility and saving, it is not yet practically available for the complete process. Spent oxide of iron may be considered a residual, as it contains some 50 per cent. to 60 per cent. of free sulphur, which is converted into sulphuric acid at the works of the Gas Light and Coke Company, and the Sheffield and Commercial Gas Companies, and the resulting acid is used to fix the ammonia as sulphate of ammonia. Further, the waste sulphuretted hydrogen evolved from such manufacture of sulphate of ammonia may now be considered a valuable residual at works which manufacture sulphuric acid. The vapours yield an important amount of acid, and in this way a complete economic cycle of reactions is maintained between the various impurities. Lastly, the spent lime is re-burnt into caustic lime by use of the breeze and ashes in a Siemens regenerative furnace, lime being essential for removal of carbonic acid and for the elimination of bisulphide of carbon. Thus it is seen that the carbonizing process furnishes as residual products the materials chiefly necessary for purification, and that the impurities themselves constitute valuable residuals, capable of converting one another into more useful and available forms. These reactions must be kept in view in designing works, so as to provide the facilities necessary without undue cost for transport.

Storage of Gas.—The larger sizes of gasholders and tanks almost always work out cheaper per unit of capacity; hence the advantage of large undertakings over small in capital economy. Primarily, whatever may be the situation, no engineer now neglects the saving arising when a telescopic holder of two or more lifts is constructed, instead of single holders, as formerly; because the cost of the tank is practically unaltered thereby, while the storage may be doubled, trebled, or quadrupled. As the tank will generally cost as much as a single lift of the holder, and an additional lift costs little more than half the first single lift (leaving out

the crown, and only adding cups and guide frames), clearly the capacity can be trebled for 50 per cent. additional cost for the whole.

Leaving these general observations on obvious points, which are only mentioned because they have sometimes been notably disregarded, and coming to the cost of construction, the tank constitutes the most difficult part of the work, and that in which the greatest saving can be secured. Formerly tanks were invariably constructed in masonry or brickwork backed by clay puddle, the whole being excavated to the full depth from the surface; or, if springs or faults in the foundations made this construction impossible, they were constructed in heavy cast-iron segmental plates bolted together with flanges and further strengthened circumferentially by steel or iron belts at short intervals in their height, the whole being carried upon a concrete base of adequate area and thickness. Often the greater part and sometimes the whole of these were fixed above ground, according to the foundation. If the brick-and-puddle tank was expensive, the cast-iron tank with belts and artificial foundations was very much more so, costing in the Author's experience three times as much; owing to the thickness of cast-iron necessary for the lower rings of the tank, the difficulty of getting sufficient bolt-area and flange-strength at the joints of the segments, the cost of the belts, and the difficulty of securing their due and adequate tightening.

With the ordinary form of brick-and-puddle tank the cost of construction in a district where clay could not be obtained was greatly increased, as the whole of the materials had to be brought from a distance. This consideration, coupled with the fact that materials suitable for making concrete were almost everywhere available, and that cement of a high tensile strength was cheaply procurable, led to the adoption of concrete for tanks, wherein watertightness was secured by a thin rendering of neat cement or cement plaster on the inner face of the walls, as distinguished from the thick (between 1 foot 6 inches and 2 feet) backing of watertight puddle to the brick or masonry walls. In the cement plaster any failure or crack could be readily seen, while in the puddle backing if any defect existed it could not be discovered and repaired without extensive excavations, which considerably weakened afterwards the earth support to the wall and foundations. Substituting Portland-cement concrete at 10*s.* per yard for brickwork at 24*s.*, and dispensing altogether with the puddle, which cost often 6*s.* a yard to prepare and much more to place in position, and, moreover, avoiding the distortion of the true internal

face of the brickwork wall, which often arose from the pressure and slip of the puddle, not only expedited the work, but at once brought about a great saving, and of late years a large number of the more important tanks in the South of England have been constructed in concrete. Moreover greater strength and stability were secured by the use of cement-concrete, as contrasted with brickwork walls backed by puddle. Mr. Livesey, Mr. Paddon and the Author have almost invariably used cement-concrete tanks, where special circumstances did not compel the construction of tanks above-ground on artificial foundations.

In such special cases the modern production of mild steel at a price and with a tensile strength which beats cast-iron completely out of the field, affords a means of meeting special difficulties without any great additional cost; and in the last few years a number of steel tanks have been erected at a cost which compares very favourably with that of concrete tanks. In durability, of course, there can be no comparison, and without further experience it would be unwise to say more than that with due attention to the painting of the metal-work above ground and to asphalting the portions buried, there is probability of as long a life for the steel tank as will make the difference in cost practically negligible.

1. A concrete tank in 1900, for a three-lift gas-holder containing $1\frac{3}{4}$ million cubic feet, cost £5,790, or £3 5*s.* 10*d.* per 1,000 cubic feet. (Fig. 7, Plate 2.)

2. A brick-and-puddle tank for a three-lift gas-holder for $2\frac{3}{4}$ million cubic feet would cost at the present date, in clay soil (the most favourable) £14,700, or £5 9*s.* per 1,000 cubic feet.

3. A steel tank for a four-lift holder, for $\frac{3}{4}$ million cubic feet, constructed in 1899, cost £5,220, or £6 18*s.* per 1,000 cubic feet.

4. A cast-iron tank, designed in 1897 for a three-lift holder, for $\frac{3}{4}$ million cubic feet, was estimated to cost £8,975, or £14 5*s.* per 1,000 cubic feet, and was not carried out.

Gasholders.—In pursuance of the considerations referred to previously, these are usually constructed with three or more telescopic lifts. Mr. Livesey has used as many as six lifts. Where future growth is foreseen, the design preferred by the Author is that with three lifts, putting in one lift to commence with, fitted with a cup, and allowing space in the tank for adding a second and ultimately a third lift. These naturally cost more when added at different periods and the question is one of balance of advantage and ultimate saving, dependent on the rapidity of the development of supply.

The chief features of economical construction followed in recent practice are :—

1st. The entire use of steel.

2nd. The abandonment of metal trussing to the crowns, thereby reducing the floating weight, which tends to be excessive with three or more lifts, and cheapening the cost. The crown and roof when landed rest upon a timber stage permanently fixed in the tank. (Fig. 7, Plate 2.)

Lastly, the guide-framing, instead of consisting of a comparatively small number of cast-iron or latticed wrought-iron or steel standards, tied and strutted together by several rings of girders and braced by diagonal tie-rods of round iron, is now simply, cheaply and efficiently replaced by a larger number—say twice as many—vertical members of rolled-joist section, strutted at short intervals by horizontal joists or girders, and braced by flat bars of steel. Thus the entire framing resembles a single lattice column large enough to enclose the holder, and having the rigidity of the entire framing and gasholder increased by doubling the points of contact, there being as many sets of rollers on each lift as there are vertical members of the framing. This formation gives double the number of attachments to the tank, the method preferred being the concreting in to the foundation of the tank if a metal one, or to the wall of the tank if a concrete one, of the length of 18 inches or so of the entire section of the standard, having brackets projecting from the sides and back of the standard to grip the surrounding concrete. During the construction, wedge-shaped openings of the necessary depth are left in the concrete, for the purpose of adjusting the standards before finally concreting them in.

One important point in all guide-framing is that the guide-bars on the upper framing and in the tank shall be coincident and continuous, so that the bottom roller on the gasholder cannot escape the guide-bar at any point between the floor of the tank and the very top of the gasholder guide-framing. Some accidents investigated have arisen from fouling or failure of the guide-rollers or bars, causing hitching up of the roller or other projection from the holder. This gives rise to lurching and tearing of the plates, and if once there is extensive leakage of gas, the holder is wrecked by collapsing like a balloon, which it greatly resembles, as it depends on the gas for floating in the water, and has necessarily very little strength in the shell or skin. The latter is quite incapable of sustaining any great strain or abnormal pressure, and therefore, of course, its roller-bars, cups and angle-connections are duly strengthened by special framing.

The cost of such a holder for 1¾ million cubic feet completed in 1900 was £8,590, or £4 18*s.* 1*d.* per 1,000 cubic feet, and that of a similar holder in 1898 for ¾ million cubic feet was £5,000, or £6 13*s.* per 1,000 cubic feet, another illustration of the effect of the scale of operations reacting inversely on cost per unit of capacity.

Distribution.

Economy in capital outlay is secured, and much waste is avoided, by laying, in the first instance, mains of liberal calibre, having regard to the small difference in cost between the smallest cast-iron pipe now generally made (2 inches in diameter) and the more useful 4-inch pipe having a delivery power, for the same length and pressure, nearly six-fold greater at a cost only one-half greater. Especially should be borne in mind the inevitable necessity of replacing sooner or later the 2-inch main by one of larger size, with the consequent cost of relaying and the still larger cost of repaving, accompanied by loss of part of the pipes removed. In places offering the poorest immediate prospect of consumption, a pioneer 4-inch main should be laid on one side of a new road to be supplemented later by a second main on the other side, which, if the general development requires it, may be of such increased calibre as will enable it to perform an arterial or carrying duty beyond its own extent.

The main arteries should be as few in number and of as large a diameter as possible, in order to give the largest duty from the weight of metal employed and with the least friction. Pipes can now be cast of practically any diameter, and economy of space occupied in the roadway, as well as economy of capital, demands that instead of multiplying mains and wasting metal, labour, and paving-expense, besides incurring excessive friction, arterial lines be as few, as direct, and as large as possible.

Nothing in this department saves capital in the long run like careful investigation of these points, and the relief of revenue from the renewal-charge incidental to the replacing of arterial mains by larger ones from time to time is also very great.

Within the past year, in the suburbs of London, a 30-foot road was opened for a 24-inch main to be laid, and was found to be occupied by eight pipes of another company as follows :—one 36-inch, one 30-inch, one 16-inch, one 15-inch, one 9-inch, one 7-inch, one 6-inch, and one 4-inch pipe, having an aggregate weight of 3,390 lbs. per yard. It is impossible to conceive that all these separate mains were necessary for any useful purpose whatever, while their

collective capacity could have been provided by one main weighing 1,946 lbs. per yard, and 48 inches in diameter, or by two mains, each weighing 1,320 lbs. per yard, and 36 inches in diameter.

From the foregoing it is clear that economy must always be on the side of large undertakings as compared with small ones, in the ratio of capital expenditure per unit of sale.

Mains.—Pipes are now made universally of a more uniform thickness of metal round the whole circumference, as they are cast in vertical instead of, as formerly, in horizontal moulds, wherein the core was frequently strained, giving an eccentric casting. They are made in lengths of 12 feet instead of 9 feet thus saving 25 per cent. of the jointing and the metal in sockets. They are found to be practically everlasting when laid in ordinary soils, and their life may be taken as limited only by their being overtaxed by growth of consumption and having to be replaced by mains of larger calibre. The pressures under which mains are generally worked do not exceed 3 to 4 inches head of water, but by means of Sturtevant fans these pressures have been raised by Mr. C. C. Carpenter, M. Inst. C.E., on special connecting-mains in the district of the South Metropolitan Gas Company, to 12 inches and 18 inches head of water. In America, by use of steam-pumps, pressures of several pounds per square inch have been reached, increasing the flow in the ratio of the square root of the additional pressure used.

Electrolysis.—Electrolysis by the return-currents of electric tramways and railways begins to give evidence of its occurrence on the mains of the South Metropolitan Gas Company and on the gas- and water-mains in Manchester, Preston, and elsewhere. In America, where electric traction has been longer in use, serious damage has accrued from this cause and special legislation has been directed to its prevention.

Owing to the modern system of paving with wood or stone bedded on concrete—especially with the former where there is diagonal boarding under the surface-blocks—the cost of disturbing the pavement for renewal or repairs is almost prohibitive; and as it further causes great delay and difficulty of access, the gasworks engineer is tempted to hope for an extension of subways in such places, even at a rental for their use. The cost of hardwood paving on diagonal boards which rest on 9 inches to 12 inches of Portland-cement concrete varies between 21*s.* and 24*s.* per square yard, and much increases the labour of stripping a main or laying a service-pipe. Subways, however, costing as they must do some £9 to £12 per lineal yard in new streets, would cost con-

siderably more in existing streets owing to the expenses attending removal of the subsoil, and the obstruction to traffic. The Author laid gas-mains in the first subway constructed by the Metropolitan Board of Works in Southwark Street, Blackfriars, and demonstrated the feasibility of doing so without injury or risk. This was done under the direction of Sir Frederick Bramwell and the late Sir Joseph Bazalgette, Mr. Hemans and Mr. Robert Jones, MM. Inst. C.E. Mains of 18 inches, 10 inches, and 6 inches in diameter were so laid in 1867 for the satisfaction of the Parliamentary Committee, by whose direction Professor Graham's indicator of percentage of explosive gas was used in the subway. This subway was followed by others in Garrick Street, the Thames Embankment, Commercial Street, and Queen Victoria Street. They are available for all public services requiring subterranean connections, and a reasonable rent is charged for the accommodation afforded.

Service-Pipes are now being laid, according to the Author's practice, of steam-tubing, which is 30 per cent. thicker than gas-tubing, and is expected to endure without renewal for an even longer period than is represented by this additional thickness. The wrought tubes are all coated with tar after being screwed together. This is preferred to painting or tarring them previously, as the tongs in screwing up always pierce and remove any coating already on the pipe, and, although this only affects a trifling portion of the service, it necessarily damages the whole length. The drilling and tapping of the mains and the screwing of the service-pipes into them are now always done by special tackle, which prevents gas from escaping. The life of a service-pipe is determined largely by its situation and its protection from leakage of water from the gutters in the roadway, and by the nature of the soil; but under the new and more expensive methods of paving on cement-concrete foundations the endurance of such pipes is largely increased, and the life formerly attributed to them may be taken to be considerably extended. Service-pipes were formerly renewed every 12 years or 14 years; this period has been extended to 20 years or 21 years.

Meters.—In former days wet meters were universally employed, and for accuracy of registration they are still the best, but the superior convenience of the dry meter has made it such a favourite with the public, that it has practically displaced the wet type, and, indeed, it is now so well made that meters of the best makers have been found after so long as 15 years' to 20 years' continuous use to register correctly within 1 per cent. of error.

They should, however, be tested at least once in every 6 years or 8 years. Formerly their extreme life was considered to be 12 years, but they are now found to work well up to 16 years and 20 years.

Conclusion.

If the various factors in economical construction enumerated in the foregoing be kept in view and studied, the constructing engineer can at any rate congratulate himself that he has placed the undertaking in the most favourable condition for meeting the public wants on that footing of cheap supply which secures the most satisfactory relations with consumers, and the best interests of the undertaking. He will need to supervise the practical working of the plant, and to see that the best possible results are obtained from the raw material as well as in the reduction of labour.

It is unfortunate that those responsible for considerable undertakings are often neglectful of securing the services of competent engineers, and offer remuneration quite insufficient to procure adequate technical qualifications. Abroad, a very different view is held, and even at comparatively small gasworks is to be found not only a commercial and financial general manager, but also a trained engineer who has almost invariably obtained some satisfactory diploma in science.

Necessarily in an industry involving the relations of buyer and seller in so many departments, the engineer will frequently have to be assisted by the shrewd commercial man, capable of grasping the conditions of markets, and of discerning and meeting the wants of the community he is supplying, and sometimes even of suggesting and guiding those wants. Instances are not wanting where these qualities, combined with proper technical training, have achieved marked success in popularising the use of gas and at the same time giving the highest return on the capital invested.

Reference to the Author's Paper in 1875 on kindred points shows that the higher selling-prices of gas then current in several cases were attributable to excessive capital. A further 25 years' experience gained in a wider field of observation leaves nothing to be withdrawn from the views then put forward. Indeed adhesion to those principles, and working on the lines then enunciated wherever occasion permitted, have resulted in considerable reduction of the price of gas in many localities.

The Paper is accompanied by seven diagrams, from which Plate 2 has been prepared.

Discussion.

The President. The PRESIDENT moved a vote of thanks to the Author for his admirable Paper, and recalled the fact that this was not the first Paper Mr. Jones had been good enough to present to the Institution, for 26 years ago he had contributed one which had led to a discussion extending over three evenings. So much time was not available on this occasion, the next ordinary meeting being the last of the Session, but he trusted, as there were many well-known gas-engineers present, that the discussion would be heartily sustained throughout the time at disposal.

The Author. The AUTHOR feared that, in his effort to make the Paper acceptable to members of the Institution generally, he had dealt rather with the lines of general interest, showing how the main requirement of the consumer of gas, viz., a cheap supply, could be met. Lest that might lead the members to think there was in the Paper a little too much of the general manager looking for a dividend, he would point out that in it he had urged very strongly the claims of the engineer, as responsible for the capital expenditure, to be recognised as the most potent factor in insuring a cheap supply of gas.

Mr. Brackenbury. Mr. C. E. BRACKENBURY remarked that it might perhaps be doubted whether the Author had succeeded altogether in giving an impression of what was generally accepted as the modern practice in the manufacture of gas. The arrangement of the Paper had resulted in some lack of clearness, and in overlapping and repetition. He only mentioned that small point to show that, in his opinion, although the Paper was of considerable interest, it might have gained in interest and conciseness had it been cast in a different mould. More important, however, were the omissions. It struck him as somewhat curious that a Paper on the modern practice of gas-manufacture made no mention, except incidentally, of those gasworks where all the operations, from receiving coal to the selling of the residual coke, were performed entirely by mechanical means. There were several works in existence where coal was received from either railway trucks or barges, placed in coal-stores, taken away automatically and carbonised, and the coke was discharged, quenched, and conveyed to overhead bunkers, and thence into consumers' carts, railway wagons,

or barges, entirely by mechanical operations. The difficult question of successfully conveying hot coke from the retorts might have been mentioned, particularly as it was one to which gas-engineers had given considerable attention within the last year or two; and there were now some successful hot-coke conveyors which also quenched the coke without causing trouble to the working-staff in the retort-house. There was no mention of the tendency of modern practice to replace high and bulky plant by low and compact apparatus. For instance, large atmospheric condensers were being replaced by the more compact water-tube condensers. Again, no reference was made to gas-exhausters; within the last 10 years Mr. Donkin had greatly improved their capacity by utilizing the drum, and had thereby increased the efficiency of the machine and confined it within smaller space. No mention was made of what were known as washer-scrubbers, very compact machines which were replacing rapidly the old-fashioned cumbrous and unmanageable tower-scrubbers. In the interesting account given of carburetted water-gas, space might have been found to mention the Dellwik process and its possible developments; and in the department of gasholder-construction it was curious to find no mention of the radical changes made in recent times by the Gadd and Mason spiral holders, which did away with the exterior guide-framing, and the well-known Pease system of guiding the lifts of the holder by wire-ropes. With regard to spiral holders, the company with which he was connected had erected what he believed to be the largest gasholder on that system. It was not a very large one as gasholders went, but it had a capacity of something approaching a million cubic feet, and was nearly 150 feet in diameter, with three lifts. That holder had proved so successful that it was to be duplicated in the near future. He thought the Author had claimed rather too much for the sliding-scale legislation, and the Paper might give the impression that all improvements were due more to that legislation than probably was the case. Labour troubles had played a far greater part in making gas-companies adopt mechanical appliances. The increased cost of labour and the competition with electric light had also instigated gas-engineers to find the best means of handling their material, and of producing illuminating-gas at as low a price as possible. With regard to carbonising, the Author mentioned charging- and drawing-machines driven by hydraulic power, compressed air, and direct-acting steam. Mention of direct-acting steam might lead some to suppose that it was still to be found in general use in gasworks, but such was not the case.

Mr. Brackenbury.

r. Bracken-ury. Steam had been naturally used in the first place for stoking-machinery, but there were many objections to it, and it was found now only in isolated instances for drawing the retorts, as shown in Fig. 4, Plate 2: stoking-machines of the present day were actuated almost exclusively by hydraulic power or compressed air. It would have added completeness to the Paper had an illustration been given of the compressed-air machine, which had been brought to a high state of perfection by Mr. John West, M. Inst. C.E. The Author stated that the coke from machine-retorts was not worth so much as that drawn by manual labour, by as much as 1*s.* 6*d.* to 2*s.* 6*d.* per ton. If that was the case, it was a very serious drawback to the introduction of stoking-machinery for the arduous work of retort-houses; but with the machines which he had been privileged to manage for some time in works abroad, that had not been his experience. There no complaint had been made of the coke, nor had the price of it been reduced. Turning to inclined retorts, which the Author treated rather summarily perhaps, having regard to the importance of the system, it was interesting to note that the father of the gas-industry, Murdock—whose name figured on the walls of the Institution—had started with a vertical retort and had then adopted an inclined retort, and finally the horizontal retort. It appeared that gas-engineers were now going from the horizontal retort to the inclined, and, it might be in the future, to the original vertical retort, in the shape of water-gas plant or in producing gas from coke-ovens. The idea of inclined retorts had been resuscitated by Mr. Coze, of Rheims, in 1885, and in 1889 the system had been introduced into this country by Mr. Frank Morris, M. Inst. C.E. Within 10 years very nearly 100,000 lineal feet of inclined retort had been put up in this country alone, representing an expenditure of £750,000, or an average yearly expenditure of £75,000. New works for the municipality of Birmingham were in course of construction, or had been just completed, in which there were 416 inclined retorts; and at the new works at Granton, for Edinburgh, under Mr. Herring, 504 inclined retorts were being put up. Other municipalities, such as Leeds, and gas-companies, such as the Brentford gas-company and others, had used them very largely. On the Continent it might be said that practically all new works were on that system. Yet notwithstanding this extensive adoption of the system, it was stated that the drawback of the slipping of the coal must be absolutely overcome before the system could make much headway. The keynote of the Paper seemed to be cheapness, and although

that was no doubt a very estimable thing in these days, yet it might be carried too far. He did not understand that the whole duty of the gas-engineer was merely to produce gas as cheaply as possible. He took it that it was part of the engineer's duty to maintain the efficiency of his plant and to adopt modern apparatus. There was a humanitarian account as well as a capital account, and the former necessitated the introduction of mechanical appliances to relieve the human machine wherever possible. Even if this resulted in increased cost of working, which it did not, it would be a thing to be recommended for the very severe and trying work of the retort-house. The Author evidently had a preference for manual labour, and remarked that "many of the machines have hitherto failed to attain the speed and efficiency of zealous and well-directed hand labour." But an inclined retort could be emptied of its coke and charged with 7 cwt. of coal within 30 seconds, and the average speed of stoking-machinery was sixty to eighty retorts per hour. Coal and coke could also be much more expeditiously conveyed by mechanical means than by hand. Again, the Author stated that such apparatus could be introduced with safety and real economy only in works of adequate size, yet it had been shown by actual practice that gas-works making a minimum of 100,000 cubic feet per day could successfully adopt coal- and coke-conveying plant, and even smaller works could profitably use many forms of stoking-machinery. Turning to the purifying-plant, it was not generally considered advisable to introduce steam-boilers into purifier-houses, as shown in Fig. 6, Plate 2. Several methods adopted by the Author were not generally accepted by gas-engineers. Thus, he used water-sealed valves, which in the majority of gas-works were now replaced by dry centre-valves: he cooled the gas in contact with its tar and ammoniacal liquor, while the general practice was to separate them: and he still preferred the original coke-scrubber, and stated in the Paper that coke was almost universally used for scrubbing or washing the gas with water. This latter was a somewhat startling statement, since in this connection coke had long been generally superseded by the use of thin boards, which gave far greater wetted surface than was possible with coke, in addition to many other advantages. In modern practice, however, washer-scrubbers were adopted, which could be easily regulated to the work to be done. It was no proof of the correctness of the Author's practice that, after severe testing by the authorities, very favourable reports had been given as to immunity from impurities;

Mr. Brackenbury.

r. Bracken-ıry. for what had to be shown was that equally good or better returns would not have been obtained—and in an easier, more mechanical and more scientific way—by the adoption of methods recognised as those of modern practice. The Author's liberal and sound views on distribution would be heartily welcomed and endorsed by all. Particularly should the thanks of engineers be accorded to him for having so admirably drawn attention to the importance of appointing thoroughly trained men at proper remuneration to fill the responsible technical posts in British gas-works, as was done on the Continent.

Mr. Jones. Mr. C. E. JONES congratulated the Author on having given a synopsis of the Metropolitan system. He did not intend to criticise omissions from the Paper, for it was evident to engineers that the Paper was not intended to be a complete history of the gas-undertakings in the kingdom. He agreed with the Author that reduction of capital expenditure was a very important matter. There was no doubt whatever that the gas-capital of this country stood very high, and one reason for this was indicated by the account of the eight mains found to occupy one street. That was a case in which the need for economy in capital expenditure was apparent, as one large main would do the work of all eight. Another source of economy was to be found in working gas at higher pressure than had been the practice hitherto. "Keep down your pressure" was a maxim frequently heard amongst gas-engineers; but he did not believe that the practice was in all cases economical, and if a gas-engineer could not lay gas-mains to work at higher pressures than a few inches of water it was time he employed a water-engineer to put down the mains for him. It was possible to work with pressures attaining even to scores of pounds, with the greatest ease. The increase of pressure in gas-mains would lead to a reduction of capital, because as much gas could be driven through the small main as through the large one. This practically increased the delivering-capacity of the mains without enlargement of the pipe. He would like the Author to give his views upon that point. It had been truly remarked that gasholders could be built without guide-framing, which cost between a quarter and one-third of the total cost of the structure, and that was another source of economy. He had put up the largest gasholder of the kind in Nottinghamshire many years ago, which had worked satisfactorily up to the present time. A great deal of the capital expenditure in gasworks could be saved by abolishing the guide-framing, which was not necessary, and certainly was not ornamental. The Author had given the cost of gas of

14 to 20 candle-power, and had also expatiated upon the improved burners and the supply of gas to burners under high pressure. Did the Author consider 20-candle-power gas at all economical from the public point of view? He himself did not. About 22 years ago he had submitted a Paper[1] on "Public Lighting with special reference to Streets" to a kindred Institution, in which he had expressed the opinion that gas of more than 20 candle-power was of no advantage to the general public; but now he would go farther, and would say that gas of over 14 candle-power was a waste to the ordinary consumer; if only he would burn the gas in incandescent-mantle burners he would get more light with low-pressure gas. Gas-engineering was in a state of progressive transition; formerly gas had been used for lighting only, now it was used for a variety of purposes, such as heating and motive power, for which it was in ever-increasing demand. That showed that gas of 14 candle-power was more useful for all-round purposes than gas of 16 candle-power or 20 candle-power, or even 30 candle-power. With regard to water-gas, he did not think it was likely to take the place of coal-gas. It was only an auxiliary, a help-mate; and as long as it took a subsidiary position in supplementing coal-gas, so long would it be useful. Mr. Jones.

Mr. A. G. GLASGOW considered that the very broad character of the Paper invited such abundant collateral discussion, that it would be advisable to limit his observations to that portion with which he was most concerned, viz., carburetted water-gas. He had listened with great pleasure to the Author's able and appreciative statement of the distinguishing features of that process, but he felt bound to say that the satisfaction which the Author rightly felt in the process was not eloquently reflected in the statement of cost of manufacturing carburetted water-gas given in the Paper. Practically all the items in that statement indicated arithmetical error, or, perhaps he might say, a conservatism which approached inaccuracy; probably due to the fact that arrangements had not been completed for measuring the volume of the carburetted water-gas produced. If normal quantities were substituted in the items of "oil," "coke," and "purification," the estimate would be reduced by about 3*d.* per cubic foot for 20-candle-power gas, or if the whole quantity of the oil were used, the illuminating power would be increased to about 25 candle-power. Such amended figures would accord with the Mr. Glasgow

[1] Read at Birmingham on 1st May, 1879, before the "Midland Association of Gas Managers."

Mr. Glasgow. working of the Author's installations upon numerous occasions when they had been under special study, but in no case would a comparison of the manufacturing accounts of the two gases, when manufactured concurrently, represent the financial benefit accruing from carburetted water-gas. The auxiliary production of carburetted water-gas, as had been pointed out by the Author, enhanced the price of coke, obviated the use of cannel enrichment, took care of the "peak" load in winter and of emergency variations and burdens otherwise borne by the retort-house, and enabled the retorts to be operated under practically constant load. All the advantages thus obtained went to the credit of coal-gas in the accounts. The means whereby these economies were obtained, being a burden on the water-gas plant, was charged against that gas in the accounts, and very rightly, so far as accounts went. But this was a question where common sense was called for rather than strict book-keeping, and he might remark in passing that no one was better able to exercise this common sense than the Author. By an odd coincidence he had received that morning, quite unexpectedly, a statement of the results, for the 6 months ending 31st December, of a large gas-undertaking, not in London, where the manager for his own information had made an estimate of what his gas would have cost him for that 6 months had it been all coal-gas, as against what it had cost when a certain portion had been carburetted water-gas. His figures were worked out in total sums. £88,000 odd was what the gas would have cost if it had been all coal-gas; the actual cost had been £68,000 odd, a difference of £20,000 in 6 months. That difference in the year would have paid for the entire carburetted water-gas works. The percentage of water-gas used was not stated, but he thought it would be about 30 per cent.

Mr. Carpenter. Mr. CHARLES CARPENTER thought the Author was to be congratulated on his very able Paper, especially considering the fact that at the outset he had been confronted with the difficulty of making it interesting to the many while valuable to the few. With regard to the water-gas question, he was not a maker of water-gas, but he would make a few remarks from the point of view of the user. He objected strongly to the use of water-gas as a means of getting over what had been called the peak of the load. Every now and then, as a consumer, he had a dose of water-gas sent into the mains for the purpose of getting over the peak difficulty, and it was not at all pleasant. It upset the working of the gas-fires in the winter-time, and was not satisfactory in the incandescent-mantle burners. Care should be exercised in seeing

that in all alterations of methods due regard was paid to the interests of the consumer. He had no objection to water-gas itself, but if it was used care should be taken in mixing it with the coal-gas, and the mixture should be, as nearly as possible, uniform. The Author had given a great deal of information with regard to stoking-machinery, but he had not said very much on the use of inclined retorts, and the Paper had been adversely criticised on that score. It was becoming more and more admitted that the use of inclined retorts entailed the use of suitable coal; and when that was admitted it put the use of inclined retorts on a very different basis from that on which it had been originally advocated. It was said that with many kinds of coal it was absolutely impossible to use inclined retorts, owing to the fact that in the process of carbonising the coal slipped down to the lower end of the retort. Within the last four or five weeks he had had the opportunity of trying a well-known north-country coal, which gave very good results in horizontal retorts, and when that coal had been used in inclined retorts which, with suitable coal, produced between 10,200 cubic feet and 10,300 cubic feet per ton, the yield had fallen to 8,760 cubic feet. It was a striking fact that, with the carbonising-plant in admirable order, with regular heats, and with every advantage for obtaining a high yield of gas, 10,200 cubic feet to 10,300 cubic feet of gas, and perhaps even more, per ton, could be obtained from a suitable coal, yet with certain kinds of coal unsuited for such work, owing to the fact that the coal did not rest in the position in which it was charged, the make fell to 8,760 cubic feet per ton. That was a fact which those who had any thought of using inclined retorts should bear in mind. With regard to stoking-machinery, he had had some experience in using that which had been described by the Author, and he had no doubt most engineers would prefer it in cases where the method of charging by gravitation was suitable. The disadvantages of machinery were not so serious as at first sight might be imagined. He did not consider that it should be a drawback to a system of charging retorts that it entailed the use of machinery. It was within the province of engineers to design machinery to work in a dusty retort-house as well as in the more cleanly engine-rooms, such as those of a water-pumping plant. It was only a question of finding the most suitable method of actuating the various parts and of adapting them to the work they had to do. It was the engineer's business to fit the machinery to its work, and if that was done very good results should be obtained. Another interesting point raised by

Mr. Carpente

Mr. Carpenter. the Author was the use of high-pressure mains. Perhaps, without knowing it, the South Metropolitan Gas Company had taken a leaf out of the electrician's book. In South London, having an area of 50 or 60 square miles, instead of supplying gas at a pressure about equal to that at which it was sent out of the works, high-pressure "feeders" had been used, on Mr. Livesey's suggestion. The mains from the works carried gas at high pressure into the hearts of the respective districts, where the smaller mains were supplied at lower pressure, and the result had been enormous reduction of the capital outlay in expenditure on gas-mains. Instead of an initial pressure of 3 inches or 4 inches head of water, a pressure of several times that amount was used, and the system had worked admirably. When the large amount of capital invested in gas-mains was considered, it was very important that the greatest possible duty should be obtained from them, and that object was attained by working them under the considerably higher pressures which Mr. Livesey had advocated. The maximum pressure on the high-pressure mains under this system was at present about 12 inches to 15 inches head of water.

Mr. Cross. Mr. F. W. Cross remarked that it had been his privilege to design and erect some inclined retorts during the past year. He had started with a rooted prejudice against coal-elevators and conveyors, and the question had arisen, what method should be adopted with inclined retorts for dealing with the coal. After much consideration it had been proposed to use hydraulic power. The design of the works was a modification of that shown in Fig. 5, Plate 2. On the right-hand side there was a coal-store running the whole length of the retort-house, 30 feet in width, and the side wall of the retort-house formed the wall of the charging-floor, of the hopper-floor, and also of the floor level with the top of the hoppers; there was a semi-circular roof rising from the wall on the left-hand side and extending to the wall of the coal-store. That roof, instead of springing from a height of 50 feet, as shown in the diagram, sprang from a height of 35 feet, and gave ample head-room over the hoppers and the hopper-floor. Outside that building, quite apart from the retort-house and the dust and dirt of the coal and coke, was the power-house, whence power was transmitted underground to a lift placed in the coal-store against the middle wall, the lift having a direct-acting ram and rising to the height of the hopper-floor. The coal-store had several lines of tram-rails, and tip-wagons were used in which the coal was conveyed to the lift. On the lift was a turn-table. The lift was raised to the hopper-floor, and the tip-wagon was taken off

on to the hopper-floor and run alongside the hoppers, into which the coal was tipped. The greatest difficulty had arisen in dealing with the larger lumps of coal, and it had puzzled him for a long time how to put the coal into the hoppers in such a state that it would be suitable for inclined retorts, without using a mechanical coal-breaker. At the top of the hopper was a specially designed screen. The coal was tipped on to the screen, the bulk of it fell through, and the large lumps were easily broken upon the screen by the man working the tip-wagons. He thought this was the first time such an application of hydraulic power had been made to a gasworks for inclined retorts. The power provided was in excess of the present requirements, but the works were new and he purposed to apply hydraulic power to many other uses in the works, such as hoisting the trucks of coal into the retort-house, moving the coal by grabs, and running from the power house to the lift in the water-gas plant. If in the course of time it were found undesirable to extend the inclined retorts—he was not a believer in the present absolute perfection of the system, but he believed that inclined retorts would be the retorts of the future—and the next house built were one having horizontal retorts, there was already available power for working the stoking-machinery. There was also power for an installation of stoking-machinery in the present houses. In many works where there were inclined retorts there would be a house of horizontal retorts and probably no machinery; but with hydraulic power machinery could be installed in the works. The many uses to which hydraulic power could be put in gasworks were apparent. Mr. Cross.

Mr. J. Cash considered the Paper a worthy addition to the Papers previously presented to the Institution by the Author. It was so wide in scope that it was somewhat difficult to deal with in its entirety, and he would therefore confine himself to certain points. The Author stated that when an illuminating-power was required beyond that afforded by the coal from the neighbourhood of the gasworks, the cost of enrichment inevitably exceeded its relative value to the consumer. No truer words had ever been written. There was no doubt that the product of the cheapest description of coal obtainable at a gasworks should determine the illuminating-power of the gas with which the district was to be supplied. Any excess of enrichment beyond that which the coal would naturally give was an expense to the consumer, and he was glad that a recent enactment of Parliament—he referred to the South Metropolitan Company—had dealt with that point, Mr. Cash.

Mr. Cash. and had reduced the 16-candle standard for the illuminating-power of the gas; and he thought that was one of the wisest steps ever taken. The Author had set forth very fully the advantages claimed for the use of water-gas. He was rather an advocate of water-gas; he had used it very largely in his own works for a number of years, and he was bound to say he had not found the little difficulty to which Mr. Carpenter had alluded. Probably that was because his gas was always maintained uniform in composition, the relative quantities of water-gas and of coal-gas being constant. An advantage due to water-gas which had been overlooked was the great saving of labour. No plant in gasworks was more useful to the manager in dealing with that awkward question which all had to deal with from time to time, namely, labour, and there could be no more adequate testimony to its merits than the figures given by the Author, viz., 4·59*d.* for coal-gas, and 1·91*d.* for carburetted water-gas. It was also stated in the Paper that the coke from machine-worked retorts was not worth as much as that obtained by the manual system; but he had tried machine-retorts, and had found no difference whatever in the quality of the coke produced.

Mr. Fowler. Mr. HENRY FOWLER differed somewhat from the previous speakers in that, being the gas-engineer of a large railway company, he represented to a large extent the consumer. He thought that, in discussions at the Institution, it was sometimes as well that the consumer should be a little more in evidence. With regard to the question of lighting, the Author had stated that the incandescent burner effected a saving in the ratio of 5 to 1, but he would be pleased if the Author could give any definite data with regard to the cost, with a large system, of repairs, renewals, chimneys, etc. The incandescent mantle was so rapidly coming forward at the present time that, by-and-by, gas-engineers would go about, not with a portable photometer, but with a calorimeter. Another point which not only gas-engineers but electrical engineers so frequently lost sight of was the varying intensity of light over a given area. Doubtless most members could call to mind places which were lit with lamps of high intensity placed near to the ground, the result being that in the immediate neighbourhood of the lamp itself there was intense illumination, in comparison with which the space between the lamps appeared to be almost dark. In these days of high-pressure gas-lighting that was a point which should be specially borne in mind, and the drawback could only be overcome by placing the standards at a height sufficient to give good diffusion of the light. In connection with

water-gas, one matter which appealed to him strongly was the freedom from naphthalene failures. These were a constant source of trouble, particularly on a railway, where it was essential that the light should be reliable. He had recently left a railway company to which he had been gas-engineer for about 5 years. Steps had been taken to have the failures reported and recorded, and he had no recollection of a single naphthalene failure having been reported where water-gas was used. The Author referred to the question of laying service-pipes and coating them with tar, and he would like to ask whether the Author had experienced any difficulty in getting the tar thoroughly over the pipe after it was laid. He had found that, by knocking together a rough creosoted box, in which the pipe was laid, filling the box with shavings, and then pouring hot tar over it so as to thoroughly cover the pipe, the service could be relied upon to last for many years. He had seen pipes which had been laid under these conditions lifted after being down 8 or 9 years, and the scale from the mill had still been on them. Perhaps on a railway pipes suffered more than the pipes of an ordinary gas-company, because they so often had to be laid through ashes, which was the worst material to deal with. The Author stated that the effect of the use of gas for cooking and heating was illustrated by the experience of a Metropolitan company, in whose district the daily consumption between 6 A.M. and 6 P.M. during the month of July had been quadrupled in 12 years. If the Author could give the percentage of the total daily output used for these purposes it would add considerably to the interest of that matter. Also, if the figures which were given in the Table of the sale of residuals could be brought up to date, so as to include the year which all would look back upon as the worst experienced in regard to coal, it would be more valuable. There were many small gasworks to which the various systems of charging referred to by the Author were not applicable. He believed that in England and Wales alone considerably over one-eighth of the total output of gas was from works which did not make more than 100 million cubic feet per annum. If some figures could be added, bearing on the utility of machinery in small works, to compare with those already given, they would be of great use. He was sure that all who were connected with gasworks were much indebted to the Author for his instructive Paper, and for figures which would be found very useful for many years to come. Mr. Fowler.

Mr. W. J. A. BUTTERFIELD emphasized the great economy resulting from the manufacture of carburetted water-gas, as shown Mr. Butterfield.

Mr. Butterfield. by the figures in the Table. It appeared that in June, 1900, when both coal and oil had been dear, 20 candle-power carburetted water-gas cost about 1¼*d.* per 1000 cubic feet more than 14½ candle-power coal-gas. The superficial critic might ask why the manufacture of coal-gas was continued, seeing that carburetted water-gas would give an advantage of over 35 per cent. in the value of the gas for lighting-purposes, and that analyses of those gases of the qualities named showed an increased value for the carburetted water-gas of about 16 per cent. for heating-purposes, while the extra 1¼*d.* on a selling price of 3*s.* per 1,000 cubic feet meant an increase of only 4 per cent. in cost. Therefore it would appear that the carburetted water-gas would be the better supply for the consumer, for all uses, at that slightly enhanced cost. But it had to be borne in mind that the low cost of the carburetted water-gas was due to a large extent to the fact that it was produced by the combustion of coke which was a by-product of coal-gas manufacture. If the plant were worked independently, its cost would probably be much greater; nevertheless, he believed there was an inherent economy in the process. Some 10 years ago, when the process had been first introduced into this country, figures as good as those mentioned had not been obtainable. Formerly, gas-engineers had attempted to make as good producer-gas as possible by raising the temperature of the fuel in the generator. Thirty per cent., theoretically, of the heating-value of the coke consumed during the blows was spent in raising the temperature of the fuel in the generator. The Dellwik process for making simple water-gas now aimed at utilizing something like 100 per cent. of the heating-value of the fuel consumed during the blow. Some analyses which he had made quite recently of the products from carburetted water-gas plant tended to show that, unconsciously perhaps, the Dellwik principle had been more or less embodied in the carburetted water-gas plant of the present day. Much higher duty for the oil and the coke than was shown by the Table had been claimed by Mr. Glasgow, and the plant of which he was speaking, according to the returns from the works—the Southall Works of the Brentford Gas Company—also showed a much higher efficiency in both respects. That plant had been manufactured by Messrs. Samuel Cutler & Co., while the Author's plant had been manufactured by Messrs. Humphreys and Glasgow. Instead of 30 per cent., fully 55 per cent. of the heating-value of the fuel consumed during the blows was utilized in the generator, and the surplus heat carried forward was quite adequate to gasify the oil. It was evident that the Dellwik principle in its entirety

could not be embodied in a carburetted water-gas plant so long as carburetting was done by oil. There must be a certain amount of producer-gas carried forward to effect the gasification of the oil. He believed that the greatly increased efficiency of modern carburetted water-gas plants was due to the embodiment of the Dellwik principle, perhaps more or less unconsciously, which his investigation of the plant at the Southall Works had shown. The Author had spoken of the increased cost of purification of carburetted water-gas over coal-gas. He doubted whether there ought to be a greatly increased cost. At the time he had investigated the plant to which he had referred, the impurities had not amounted to more than 1,200 grains per 1,000 cubic feet, which was the figure given by the Author for the amount of impurities in coal-gas. Therefore he contended that, even with lime purification, entailing the removal of the whole of the carbonic acid from the gas, the cost of purification of carburetted water-gas ought not to exceed that of the purification of coal-gas. Another point to which the Author had not referred was the superior enriching-value of the carburetted water-gas. If the 20-candle-power water-gas was mixed with coal-gas of 14 candle-power in equal volumes, the illuminating power of the mixture would be higher than 17 candles; it would be more nearly 18½ candles. That property of carburetted water-gas had been first pointed out clearly by the late Mr. John Methven. It was said to be due to what was the inherent defect of carburetted water-gas, viz. that the diluents of that gas were not so well fitted to bring out the full illuminating-duty of the hydro-carbons present, as were the diluents of coal-gas. Whether that explanation was correct or not, the fact remained that carburetted water-gas had a higher enriching-value than the illuminating-power of the gas undiluted with coal-gas would indicate. Having regard to that fact, and to the low cost of the carburetted water-gas—he took the Author's figure, although Mr. Glasgow and others claimed that it should be reduced—it appeared that the enrichment of coal-gas to 16½ candle-power would cost only about one-third of a penny per 1,000 cubic feet. That was a trifling figure in comparison with the high capital charges which were shown in the Paper, and it was hard to say why there should be any demand for the reduction of the illuminating-power of gas from 16½ candle-power when gas of that quality could be had at such a low increased cost over 14-candle-power coal-gas. With regard to the removal of naphthalene from coal-gas, the Author stated that it could be fully accomplished by means of the tar. A process had recently been proposed for the removal of

Mr. Butterfield.

Mr. Butterfield. naphthalene by washing the gas with the green oils of tar. In that process ¼ pint of the oils was said to suffice for the removal of the naphthalene from 1,000 cubic feet of coal-gas. The tar from 1,000 cubic feet of coal-gas contained something like ten times that amount of tar-oils, and therefore it would appear there was an ample supply of those oils in the tar to remove the naphthalene. It was open to question, however, whether the large and expensive condensation-plant necessary to apply the tar for that purpose was cheaper and more easily supervised than the comparatively simple and compact washing-plant by which the oils might be applied directly.

Mr. Livesey. Mr. GEORGE LIVESEY remarked that the Author had gone into the subject very thoroughly, and the Paper might be taken as an up-to-date record of what was known and practised in gas-manufacture. In the Table of gas-undertakings, the Author gave the percentage of increase under various headings, and amongst others there was an increase of capital in the last 4 years of £28,227,880 or 39·8 per cent. As the Author mentioned, that was not the real increase, because in a number of cases the capital had been nominally increased. In addition to the two London companies referred to, he believed there had been certain purchases of gas-undertakings by local authorities where the nominal capital had been largely increased. At any rate those figures showed a great discrepancy—an increase of 39 per cent. in the capital and of 21 per cent. in the quantity of gas sold. He was sure the Author would never agree that such figures could be taken as illustrating what gas-engineers wished to see. He had no doubt the fact was that, with an increase of 21 per cent. in the quantity of gas sold, the increase of capital would probably be about 10 per cent., and it was to reduction of the capital charge per thousand cubic feet sold that gas-companies looked for economy in supplying gas. The Author, in dealing with labour-saving machinery, said that many of the machines as yet failed to attain the speed and efficiency of zealous and well-directed hand-labour, and he quite agreed with that remark. A man with a shovel and a barrow took a great deal of beating if he would work properly, and he believed that in many cases very little advantage had been derived from the introduction of stoking-machinery, because the work of the machine had been limited by the action of the trade unions. The South Metropolitan Gas Company was perhaps in a unique position in that matter. It had been forced into the adoption of labour-saving machines against its will—certainly against his will; it had been with the greatest regret that he had

seen labour-saving machines introduced, because he had not wished to displace labour. The work had been done by hand in a thoroughly satisfactory manner, but the saving from the use of machinery was so great that the company had been obliged to introduce it. In many cases the machinery had been introduced to get rid of the labour difficulty. With regard to the question of enrichment, the Author had expressed what was the present general opinion, and Mr. Cash had emphatically endorsed it. One of the most mischievous ideas with regard to gas-supply was that relating to enrichment. Tens of thousands—perhaps hundreds of thousands—of pounds were wasted yearly for the purpose of so-called enrichment, and that had been brought about by the local authorities. Whenever a gas-company came to Parliament, the local authorities thought it was fair game for attack, and for years past they had been pressing for an increase in illuminating-power, thinking thereby to get something out of the gas-company, and not seeing that they were taxing their own constituents; that whatever expense of enrichment might be imposed on the gas-company was repaid by the consumer; and that the latter was not a halfpenny the better for enrichment and the thousands of pounds spent in accomplishing it. A turn in the tide had taken place, and he thought the first step would be to get the best quality of gas obtainable from the available supply of coal. Another step, as Mr. Fowler had remarked, would be to consider the calorific value of the gas and not its illuminating-power. Turning to the item of wear and tear in the comparison between carburetted water-gas and coal-gas, he pointed out that wear and tear with coal-gas was put down at 4·36*d.* per thousand cubic feet sold. He believed that was the total wear and tear. There was an item in gas-companies' accounts headed "Repair and Maintenance of Works and Plant," which was the total amount expended on the repair and maintenance of the whole of the works and plant inside the station. But he thought that, for the purpose of comparison, it ought only to include the wear and tear of retorts, and he would reduce the 4·36*d.* by 3*d.*, and obtain an advantage to the coal-gas to the extent of that 3*d.*, which would make the coal-gas cost 1*s.* 2*d.* instead of 1*s.* 5*d.* per 1,000 cubic feet. Again, the tar of the oil-gas was estimated to be worth 1·82*d.* per gallon, but that was the price obtained for the whole of the tar, whereas the tar from the oil-gas was certainly not as valuable as tar from coal-gas. He was only speaking from theory, because he knew nothing of water-gas, and was rather glad he did not; but he wished the advocates of water-gas would set forth in plain figures

Mr. Livesey.

Mr. Livesey. the actual cost of the system. For many years he had been trying to find out, from the public accounts, the cost of water-gas, but without success. The Crystal Palace District Gas Company had put up water-gas plant 2 years ago, and had an engineer there who had been very ready to carry out any views that might tend to accuracy and perfection of working. The total cost of the water-gas there had been given in exact figures, and had been found to exceed greatly that of coal-gas. With regard to the use of high pressures, he could say that the South Metropolitan Gas Company had done with the laying of further large mains for many years to come. The Company had large trunk mains leading from the works, and he was of opinion that they would be adequate for many years. He owed an acknowledgment to Mr. Carpenter for the able way in which he had carried out the idea of supplying gas by means of high-pressure distribution. There had been considerable difficulty, for instance, in supplying Clapham Junction. There had been an 18-inch main leading nearly to the district, with no connections; a Sturtevant blower had been put on, and the gas had been sent under high pressure through the 18-inch main right into the district. He would conclude with a few general remarks on what was often spoken of as a "dying industry." The gas-industry had never been so much alive as it was at the present day, and, he thought, had never had such good prospects. He had taken the trouble to ascertain what had been the increase in the consumption of gas in South London, and he was able to make a rough estimate, which, however, was not far from the truth. In the year 1840 the total consumption of coal for the manufacture of gas in South London had not exceeded 20,000 tons; in 1870 it had been 200,000 tons; in 1890, 700,000 tons; and in 1900 over 1,200,000 tons. In the first 30 years there had been an advance in the coal-consumption of not quite 200,000 tons, in the next 20 years an advance of 500,000 tons, and in the last 10 years an advance of another $\frac{1}{2}$ million tons. The consumption of coal in 1900 by the gas-companies in South London, mentioned as exceeding 1,200,000 tons, did not include the large southern suburban companies, which added a further 250,000 tons. In another respect there had been great advances in the use of gas. In looking over a drawer in his workshop he had come across some of the original burners, which had reminded him that originally gas had been burnt in the worst manner possible. The first burner had been a single jet, and not content with making it a single jet, the designer had made the aperture in the burner as

small as possible—a needle would hardly pass into it. To increase the light the number of jets had been increased. One of his early experiences as a school-boy had been the stock-taking during his holidays at Midsummer, when his father had given him 6*d.* a day to assist, and part of his work had been counting the burners—so many one-hole, so many three-hole, so many seven-hole burners, and so on. He did not think one candle-power per foot per hour had been obtained from those jets. Then about 1860 Mr. Sugg had made the discovery that the gas ought to pass through larger apertures, and had introduced the London Argand burner, and thus obtained a duty of 3 candle-power per cubic foot of gas burned per hour. There had also been the old inferior fishtail burners and batswing burners, improved by Mr. Bray, as well as by Mr. Sugg. Then had come, about 1880, the Siemens regenerator burner, which had given 6 candle-power per cubic foot per hour; and that had been followed by the Welsbach burner, which had doubled the illuminating-power again, making it 12 candle-power per cubic foot per hour, or 60 candles for 5 cubic feet per hour from so-called 16-candle-power gas. The improved Welsbach burner had doubled it again, making it 20 candle-power to 24 candle-power per cubic foot of gas per hour. Now, by the high-pressure Welsbach system, 30 candle-power per cubic foot per hour could be obtained. So that under the most favourable conditions a consumption of 5 cubic feet of gas per hour would give as much as 150 candle-power, whereas 70 years ago it had only given 5 candle-power. Taking that into consideration, as well as the vast increase in the output of gas, some idea might be formed of the enormous increase in the amount of light derived from gas. He could assure Mr. Fowler that the gas-companies regarded the consumer as their best friend, and were anxious to do everything possible to meet his wishes. The difficulty with regard to the Welsbach mantle was that the ordinary consumer could not be troubled with it, and the South Metropolitan Company were undertaking to supply and maintain mantles at a charge of 1*s.* per quarter per light if the lights did not exceed six in number, and of 9*d.* per quarter per light if the lights exceeded six. Some large consumers, such as shop-keepers using, say, 150 Welsbach burners, were having them maintained by the Company on those terms. The gas-industry had been in existence for 100 years, and he saw no reason why it should not go on progressing at a rapid rate. It had captured the working man and had brought about the use of gas in working-class houses to a wonderful extent. What was required was that young men of ability should enter this

Mr. Livesey.

Mr. Livesey. branch of the profession. He was afraid they rather looked down upon it. Recently he had had the great privilege of going over the magnificent works which the President was carrying out in Mid-Wales, and he could not help a feeling of envy and a wish that he had been a waterworks engineer. But there was wide scope for the gas-engineer, and his occupation was a most interesting one. There were many things in it which required the attention of the ablest men, and one of them was to produce gas as cheaply as possible. He looked back to his early days, when he had nothing to do but to look after the working part of the business, with the greatest pleasure and satisfaction. He pleaded for the entrance of young men of ability into the profession of gas-engineering, and predicted a good future for them.

Mr. Woodall. Mr. CORBET WOODALL always listened to the remarks of Mr. Livesey with pleasure, especially when he was speaking on matters with which he was so fully cognisant. He had no doubt whatever that a few years hence Mr. Livesey would have an equally interesting story to tell about carburetted water-gas and its relations to the general supply, but with a very different conclusion. He concurred in what Mr. Livesey had said with regard to the development of the light from gas by means of improved burners; but he deprecated the emphatic condemnation of those who had in times past advocated an improved illuminating-value for the ordinary gas supplied. It was rather a case of being wise after the event. Mr. Livesey's observations were correct, but it was not necessary to condemn those who, before the incandescent burner had been introduced, had been willing to improve the value of gas, and had performed a public service by so doing. He emphatically supported the suggestion that there was still in the field of gas-lighting an opening for young men of education and energy. He believed, and the belief was supported by the experience of many years, that there was still in gas-supply possibly as wide a field for development as there was in the great field of electricity. The last few years had seen developments of a very remarkable character, not simply those affecting the amount of light to be obtained from a given quantity of gas, but also in the recovery of unexpected products from the distillation of coal, which had conduced materially to the reduction of the cost of the original fuel. The Paper dealt with a wide subject, and he was surprised that it had been founded upon observations over a very limited field. In speaking of the improvements which had taken place in the modern practice of gas-manufacture and distribution, it was surprising

that attention had not been given to what had been done in other countries. Continental engineers were sometimes more logical and careful in their scientific and exact investigation than were gas-engineers at home, and the development that had taken place on the Continent was very striking. Incidentally he would like to put in a plea for a little more combination between the chemist and the engineer than had been customary. Apart from the Continent, he thought there was as much evidence of development in the provinces as in London. He doubted very much if the majority of gas-engineers in the country would say that in coming to London they were coming to the ultimate evidence of progress in that particular direction. The observations of the Author with regard to economy in the expenditure of capital would appeal to everybody; they were, so to speak, accepted gospel. At the same time, where capital expenditure was productive he would be very sorry to see it spared. He did not think the utmost had been done when an appliance had been bought at the minimum cost and had been housed as cheaply as possible in a gasworks. Something was due to the neighbourhood in which the gasworks was placed and the engineer's feeling of pride in the work done. He felt that when the modern Edile, for whom the souls of many people longed, was found and appointed, he might take under his wing not only some bridges of less pretentious character than those referred to in a recent discussion at the Institution, but also bridges which crossed the streets of towns, and the lamp-posts with which the streets were adorned. When that day came, Mr. Woodall would be willing and glad to hand over to him some of the structures with which gas-engineers had disfigured the towns which they served; and with regard to some structures the censor would certainly be disposed to remark, "You say it was very cheap, but I am quite sure, whatever it cost, it is dear at the price." The late Mr. Thomas Hawksley had built many gasworks in England, at considerable cost, but those works were standing now very much as Mr. Hawksley had built them, and the people of the towns which they served were proud of their works, and considered them rather an ornament. The Author had referred to the great advantage which resulted from the introduction of the sliding scale as a means of governing the price of gas and the profit of the gas-shareholder. He was of opinion that the sliding scale had been an advantage on both sides, particularly because it had satisfied the general public that there was a community of interest between the makers and users of gas. But it was certainly a mistake to credit the sliding scale

Mr. Woodall.

Mr. Woodall. system, as had been done, with all the economies which had resulted since its introduction. Comparing the prices charged to the consumer at the present day with the prices charged, say, in the year 1876, it would be found that practically the whole reduction in price that had taken place in the interval had been due to the reduced net value of coal, and to the reduction in the charge for capital which had resulted from the compulsory sale of stock by auction. That was a point worthy of notice. The Paper had not dealt to any large extent with recent construction, but he was surprised at the uncertainty that appeared to affect the Author's mind with regard to inclined retorts. There was hardly a retort being built in Continental works which was not upon that plan, and he knew of several works in England where coal was now being distilled in no other retorts but those on the inclined system. He had the greatest respect for Mr. Carpenter's opinion, but he thought the difficulty that he had found with regard to the creeping or sliding of the coal in the retorts could be met, and was met, comparatively easily by blending the coals, so that those which had a tendency to creep down were held by those which had a less tendency, or none at all. The system itself was a very charming one, and was distinctly economical in use. If he were to place in order of importance the improvements in gas-manufacture which had taken place in modern times, they would be the introduction of labour-saving machines, the introduction of carburetted water-gas, the improvement in the firing of retorts by the introduction of gaseous firing, and the regenerative principle. There were works now where the coal was picked from the ship or from the truck, carried to the retort and passed through it; and where the coke was taken out and carried away, lifted into hoppers and loaded into trucks or barges, without being handled at all except by machinery. That, combined with the introduction of water-gas, had improved the conditions of labour, and had made the conduct of the business of a gas-company much more pleasant, both to the men themselves and to their chiefs, than it had been in days gone by.

. Hawksley. Mr. CHARLES HAWKSLEY, Vice-President, thanked Mr. Woodall for his appreciation of the designs of his late father, who had always endeavoured to make gasworks not only such as would last, but such as would disfigure the neighbourhood as little as possible. With regard to the supply of gas during the day, perhaps sufficient attention was not paid to the overlapping of the day and evening consumption, say, between 4 o'clock and 6 o'clock on a winter evening. Warming went on in the evening as well as

during the day, and the consumption of gas was the same. The consumption for cooking depended largely on the kind of district which was being supplied, viz., whether it was the habit of the people to dine in the middle of the day or in the evening. With regard to inclined retorts he was not able to speak from actual experience, but he had had occasion recently to visit a gasworks in the North of England where north-country coal was employed, and there the inclined system of retorts was giving complete satisfaction, as he had been informed by the engineer. The only way, he thought, of employing lattice framing for gasholders would be with lattice-work similar to that of a waste-paper basket, within which the gasholder was placed. He was glad to say that the subject of electrolysis had now received recognition by Parliament, which within the last few weeks had given protection to a gas-company in regard to any injury which might be done to its pipes and apparatus by electrolysis or by fusion. Now that Parliament had begun to recognise that principle it was very likely that it would be applied in future to nearly all cases in which public bodies or companies sought to introduce electrical power into a town. On the question of carrying pipes through subways, he did not know whether the Author had forgotten that it had given rise in more than one case to considerable damage, and to some loss of life, by reason of explosion. Mr. Hawksley

The PRESIDENT remarked that Mr. Livesey had referred to the gas-industry as not being a dying one; at all events Mr. Livesey was a very "live" man himself, and would not allow gas to die for want of a powerful advocate, and the President hoped that his predictions as to the future of the gas-industry would be verified. Mr. Livesey's depreciatory remarks about carburetted water-gas were hardly justifiable after his confession of only partial acquaintance with the subject. He heartily congratulated the Author on the animated discussion which his Paper had evoked. The President.

The AUTHOR, in reply, was glad his Paper had produced so good a discussion, but he almost wished his statements had been handled more vigorously. The explosions mentioned by Mr. Hawksley had been confined to Paris, none, in his recollection, having taken place in London. Those who knew what the pulling up of the streets in London meant to the undertakers, as well as to the users of the streets, would agree that some accommodation for mains, such as subways, should be provided. Mr. Woodall favoured gasworks in which the whole of the work was performed by machinery; such works were shown in Fig. 3, A and B, Plate 2. The coal was grabbed out of the ships, taken away The Author.

The Author. in railway trucks, shot into the stores, turned into coke, shot into the cellars below, taken away by wagons and put into the barges without handling at all. With regard to hand labour, he cordially endorsed all Mr. Livesey had said. Anything more delightful to witness than the smartness, the neatness, and the efficiency of a gang of men charging retorts in the old-fashioned way he could not conceive. He found considerable difficulty in making managers see that for works below a certain size the best possible machine was the human machine, because a man directed his energy with judgment. With regard to the blending of coal, he would leave the question of inclined retorts in the hands of Mr. Carpenter, than whom no abler critic could be found. But in handling, as was done in London works, hundreds of thousands of tons of coal a day, blending was difficult. He had seen a splendid installation of inclined retorts in Mr. Carpenter's works, the retorts being fed and discharged admirably; but Mr. Carpenter had shown him records taken a fortnight previously, in which, owing to the use of another variety of coal, the good return had disappeared, because the coal had slipped down and had not been perfectly carbonized. Works must be made to suit the vicissitudes of trade; therefore they should not be limited to the coal of one particular colliery. He valued especially the crisp and vigorous remarks of his old friend, Mr. George Livesey, and felt flattered that he had lent the weight of his authority to the discussion. He had turned up recently an interesting record of coal-contracts. Coal which at the present time was put on board ship in the north at 9*s*., and which had been in the past year 16*s*., the year before 8*s*., and the year before that 7*s*. per ton, had been contracted for in 1852 at 4*s*. 3*d*. per ton. With regard to tar, petroleum tar was more valuable than other tar, but the manufacturers had not yet paid the value of it. Mr. Livesey was quite right about the wear and tear. He had put in the whole of the wear and tear of the gasworks, and had loaded the coal-gas in that way. With regard to the capital, there was a footnote warning readers of the fact that much of the increase was nominal. In preparing the Table, he had felt it necessary to state absolute facts, and those were the facts from the Board of Trade returns; but the Secretary, whom nothing escaped, had pointed out that much of the increase was purely nominal, due to conversion, and had given the footnote, correcting the Table by £13,000,000, and probably the amount was more than that. With regard to Mr. Butterfield's remarks, it was quite true that carburetted water-gas which measured, say, 20 candle-power by

itself, when mixed with other gas developed a higher illuminating-value, and the fact was deserving of the attention of scientific investigators like Mr. Butterfield. He endorsed what had been said as to the desirability of young men of good education and professional training not scorning the gas-industry. Although occasionally, as he had said in the Paper, councillors or directors did not quite see the advisability of paying proper salaries to competent men, on the whole he believed there was a great future for young men of ability who entered the profession. The greatest development of inclined retorts which had taken place in this country he believed had been at the Brentford Gasworks under his old friend and his father's pupil Mr. Morris. Mr. Van Restraat, who had been Mr. Morris's assistant at one time, had also done much to develop them. The reason why he had warned gas-engineers not to rush to water-gas unless it was required for enrichment—for which it was especially valuable—was that he had found, during the past year, great difficulty in getting oil at a reasonable price. Oil in America was a by-product, and there was not an unlimited quantity of it. He could not congratulate Mr. Brackenbury upon either the substance or the manner of his criticism. That speaker wanted to know why the Author did not describe all the washers, scrubbers, and other things with which Mr. Brackenbury was acquainted. His answer was, simply because the Paper had been limited to the appliances which he had found, from the practical experience of 30 years, enabled him to conform to the rather exacting requirements of the London gas-referees. In the case of the Metropolitan companies, the gas was tested with a rigour and microscopical research which occurred nowhere else in the kingdom. Gas-engineers outside London had not the faintest idea how, from day to day and from hour to hour, the gas was searchingly investigated on points which in other parts of the country were ignored. The companies were subjected to "forfeitures," which were very much like fines, and to which a certain amount of disgrace attached. Therefore London gas-engineers were unduly busying themselves in meeting this microscopic investigation instead of applying their time to more important matters. The Author

Correspondence.

Mr. Botley. Mr. C. E. BOTLEY remarked that the Tables furnished by the Author at page 50 amply illustrated the active and progressive state of the gas-industry, and he believed he was correct in saying that the annual increase in gas-consumption alone in recent years had been equal to the total output of electricity during the same period. As the Author had truly stated, this was largely due to the introduction of the Welsbach mantle and the coin-meter. For a long time electricity had had a monopoly in the matter of the supply of powerful light in the electric arc, but the Welsbach mantle with gas under moderate pressure was now a very formidable rival, as equal lighting-power could be obtained at much less cost than by electricity. With the Author's views on the waste of money entailed, both to manufacturers and consumers, in compelling the enrichment of coal-gas he thoroughly agreed, and it was a matter of satisfaction that Parliamentary Committees had sanctioned a departure in this respect by reducing the standard of illuminating-power in the case of certain companies. The advantages of a carburetted water-gas plant as a valuable adjunct to a gasworks were, he thought, generally recognised. The mixed gases, however, should, as far as possible, be regularly proportioned to avoid difficulties at consumers' fittings. He could not agree with the Author that coke was the best material to use in the scrubbers in the primary washing of the gas for the extraction of ammonia, because, however carefully the previous condensation of the gas was effected, the material became clogged and had to be renewed periodically. He preferred to use 3-inch drain-pipes superposed in layers, the outside edge of one pipe being over the centre of that next below. This method was quite as effective as the coke scrubber, and the apparatus could be steamed out readily, when necessary, without having to remove the contents. On the vexed question of naphthalene deposits he was unable to agree with the Author that either effective condensation or the admixture of carburetted water-gas afforded a perfectly reliable remedy, as experience elsewhere had shown. In the former case so much depended on uncontrollable climatic conditions, and in the latter on the permanency or otherwise of the carburetted water-gas employed. If this contained condensable oil-vapours it would undoubtedly help.

Mr. Botley

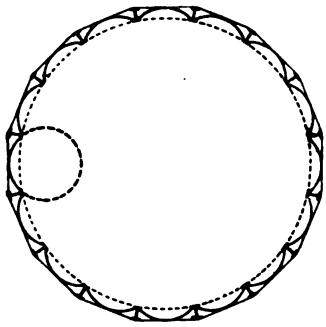
The Author, in his description of gasholder construction, had omitted to mention one system, namely, where there was only partial guide-framing provided for the gasholder. On the principles governing the construction of the guide-framing, as described by the Author, he thought most engineers were now agreed; but his experience had been that the guide-framing for the upper lift of the holder might be safely dispensed with, provided due attention was paid to the proportioning of the curbs and grips and the accurate working and setting of the guide-rollers. Considerable economy in construction and in subsequent maintenance was secured by this method, of which he could speak with confidence, having constructed several gasholders in this way. The Author's views on the outlay of capital and the strict necessity of eliminating obsolete capital, were such as commended themselves to all who had the welfare of gas-undertakings at heart, in the interest of both consumers and owners, who should be jointly considered. Too much, however, was, he thought, made of the value of a monopoly in gas-supply, especially where a corporation owning an electricity-undertaking were competing against a gas-undertaking. The monopoly was hedged round with restrictions and responsibilities which minimised its value, to a very large extent, while the corporation had a free hand. As regarded the training of engineers for the conduct of gas-undertakings, the Author had struck a sympathetic note and had put forward a plea which it was highly desirable to take to heart in the best interests of the profession.

Mr. Cripps.

Mr. F. S. Cripps remarked that the Paper covered such a wide range that he would limit his observations to a few of the questions raised relating to engineering construction. The Author drew attention to the fact that much saving might be effected in the cost of gasholder-tanks by taking advantage of the natural conditions existing in each particular case. This was a truism, but it was so frequently disregarded that it was well it should be restated. Concrete tanks with rendered interior, concrete tanks with clay-puddle backing, brickwork tanks with clay backing, steel tanks above ground, were all good in their place, but it depended entirely on local conditions which form should be adopted. Cast-iron tanks were practically out of date, and at best were only suitable for tanks of comparatively small size, and therefore might be dismissed as unworthy of a place in modern gasholder design. The steel or wrought-iron gasholder-tank, however, was a useful structure, indeed it was indispensable in some situations. In

Mr. Cripps. ground saturated with water alongside a river, an above-ground steel tank was the only economical structure. Unfortunately, these structures became very expensive when of large size, and had hitherto been impracticable over a certain size, owing to the enormous bursting-stress demanding an inordinate thickness of metal in the plates, a thickness which was beyond all reasonable construction. The difficulty had been partly overcome by making the sides with double plates. He had recently devised a tank having the sides looped outwards between the standards or uprights supporting the guide-framing above, *Fig. 8.* This allowed of the side-plates being made much thinner than would otherwise be necessary, for the obvious reason that each loop was the arc of a much smaller circle than that of the diameter of the tank. But the resultant outward force at the intersection of each pair of bays or loops must be resisted either by the transverse strength of the standard as a cantilever, or by a strong tie or ties uniting all the standards together in a circle. Such ties required to be of considerable sectional area to resist the tension; water-tightness not being required, it was more convenient to dispose the metal to meet the stress in this form than in the side-plates of the tanks alone. In all steel tanks fixed partly below ground, his practice had been to build a dwarf wall round the outside, leaving a space of 1 inch between the brickwork and the side-plates of the tank from the bottom upwards. This space was filled with hot pitch or asphalt, after removing any water which might have collected in it. The pitch found its way under the bottom, and completely protected the tank from rust and corrosion at the ground-line; it was weathered off at the top of the wall. In comparing the cost of rendered and of puddled tanks it should not be forgotten that in a rendered concrete or brick tank of large size the walls generally needed to be thicker, to resist the bursting-pressure of the water, than in a puddled tank, and for the following reason. In a rendered tank the watertight skin on the inside threw the whole of the bursting-stress on the brick or concrete wall, and as both brick and concrete were unsuitable for resisting tensile stress, and the backing, however solidly rammed,

Fig. 8.



could not always be depended upon to prevent the wall being displaced sufficiently to cause a crack in the rendered skin, it became desirable not only to have thicker walls, but to resort to steel or iron bands either embedded in the wall or hooping it round outside. These hoops, as well as the extra thickness of wall, should therefore be added to the cost of the cement rendering when comparing it with that of puddle. The bursting-pressure was so great on a large tank—say, 250 feet or 300 feet in diameter and 40 feet or 50 feet deep—and the displacement of the backing necessary to cause a crack, say, $\frac{1}{32}$ inch in width, was so very small compared with the diameter of such a tank, that to depend on a not very elastic material for watertightness involved an element of risk which could not be entirely eliminated from a rendered tank. Exception might also be taken to the remark that a rendered tank was easily made sound if it should leak, because the rendering showed the crack which required repair. He had known rendered tanks to crack, and to be emptied and repaired several times without avail, and the reason would appear to be that if a tank-wall cracked, the skin of course cracked with it; but when the tank was emptied the crack closed up to a certain extent, perhaps very slightly. After repairing the cracked skin and refilling the tank, the tank-wall sprang open again under the pressure of the water, and once more opened the crack; and so the process might in some cases be repeated time after time without any lasting good being effected. In such a case the only satisfactory course was to stop the crack, if possible, while the tank was full of water. It was therefore necessary to make the walls very strong and substantial in the case of rendered tanks. In rendering a tank it was of course necessary to render the *whole* of the interior. This was mentioned because he had recently had his attention drawn to a tank which had been rendered inside after fixing the tank-guides, the cement being pointed up close to the channel-guides, but the wall not being rendered behind them. As a natural consequence the tank leaked, because when the gasholder-rollers were run up and down the guides, the latter were bound to spring a little under the pressure, and so the cement was cracked away at the sides; the water then found its way behind and out through the porous wall. It might also be mentioned that the practice of letting the tank-guides into the concrete at the foot, to a depth of 2 inches or 3 inches, should never be adopted in rendered tanks; the guides should stop short at least 1 inch from the bottom. If they were let in, the cement skin was broken and the tank frequently leaked.

Mr. Cripps.

Mr. Cripps. Where the tank-guides were fixed to the wall by hook-bolts let into the wall, the bolts should be entirely bedded in cement. They should not be drawn out of the wall in tightening up when fixing the tank-guides. The guide should fit close against the rendered wall, or should be packed out if necessary. In any case the wing-plates of tank-guides should bear hard against the wall at the bolts, before tightening up, and should not be sprung back, otherwise the bolts might be loosened in the wall, cracking the skin, and causing leaks. Of course, this did not apply to puddled tanks. All sharp angles should be well rounded off in the rendering—for instance, where the wall and apron met inside. It would appear scarcely necessary to mention such obvious precautions, but mistakes like those referred to were matters of common occurrence. In practice, he had restricted rendered tanks to those of small size. These he almost invariably made with a concrete wall between 15 inches and 18 inches thick, having iron hoops embedded in the concrete, the whole of the interior surface of the tank being rendered with cement and sand (1 to 1), the skin being about $\frac{3}{4}$ inch thick. His rule was to allow half the bursting-stress due to water-pressure to be resisted by the wall and its backing, and the other half to come upon the iron bands, which were proportioned accordingly. This appeared to work well, as all tanks constructed in this way had been sound and had remained so. The bands were hook-jointed and bent to the circle of the tank. The piers to take the standards for the holder were simply formed on the side of the tank, and only extended a part of the way down the wall. They were simple and inexpensive to make. As already remarked, rendered tanks of large size required a strong wall. On the other hand, practically the only strength required in the wall of a brick or concrete tank with puddle backing was that necessary to enable it to resist the crushing stress due to the pressure of the backing when the tank was empty. Brick or concrete being eminently suited to resist compressive stress, the wall did not require to be so stout as when it had to resist tensile stress. It should be sufficiently substantial, however, to resist distortion and maintain a perfectly cylindrical shape, and the walls must be erect, or the tank-guides could not be fixed so satisfactorily; that was, they could not be made to back hard against the face of the wall for their full height, but had to be chased in, or some other plan had to be resorted to, to give them a solid bearing. From what had been said, it would be seen that it was scarcely fair to the puddled tank to set the cost of the puddle against the cost of the rendering, because the whole wall

was lighter in a puddled tank, and no iron bands were required. If the puddle was properly made and put in, it was very unlikely to leak, because the material was soft and plastic (unlike the cement skin) and would yield and spread backwards under the water-pressure to any extent which the compression of the earth backing behind might demand, without leaking. When a puddled concrete or brick tank was full of water, the wall was under very little stress. It was under very much the same conditions as it would be if it were built entirely above ground, and if no water were put into it. It simply had to carry itself and the guide-framing of the holder attached to it, together with any pressure of the backing which might not be balanced by the outward water-pressure. The wall in such tanks required to be perfectly porous, so as to allow of the water getting through and behind it and pressing against the puddle upon which alone the watertightness depended. It was true that should the puddle not be sound much trouble might arise, but this did not always involve deep excavations. Much might sometimes be effected by stock ramming, and if the doubtful places could be located, by emptying the tank and watching where the ground-water ran in from the outside through the wall (because it frequently followed that if a tank leaked outwards, it also leaked inwards after emptying), a pipe could be let into the brickwork at the leaky place and carried up inside the tank to the ground-level. Then, after filling the tank with water, Portland-cement grout forced down the pipe, aided by the water leaking out, would be sucked into and through the wall, filling up the fault in the puddle. The inlet- and outlet-pipes of gasholders were perhaps answerable for more leaky tanks of the puddle type than anything else. If they pierced the puddle, the water was liable to find its way between the side of the pipe and the puddle. They should always be enclosed completely in puddle. They were bound, however, to leave the puddle at the top so as to connect with the rest of the work. At this point, where the pipes left the puddle, the greatest care should be taken, and the puddle should be carried some distance along the pipes. It was usual to branch away from the inlet- and outlet-pipes at some distance below ground, but by taking these pipes to a higher level outside the tank than that of the water in the tank, and then branching off, this risk would be avoided. It could be minimised, however, by taking the branches off at a point nearly level with the ground-line, where the head was trifling and a leak could easily be got at if it did occur. He noticed that the Author showed the inlet- and outlet-pipes inclined

Mr. Cripps.

Mr. Cripps. to the same slope as, and lying under, the cone. This appeared to have much to recommend it, particularly for a rendered tank, as the skin was pierced where the water-pressure was least. It also kept the pipe away from direct contact with the water in the tank, except just at the top. This avoided chilling the gas, thereby obviating one of the chief causes of the deposit of naphthalene in the inlet- and outlet-pipes.

With regard to the cost of various tanks, the Author had stated that a brick-and-puddle tank for a gasholder of 2¾ million cubic feet capacity, constructed in the most favourable soil (clay), would cost £5 9*s.* per thousand cubic feet of its capacity. Mr. Cripps had designed and carried out a brick-and-puddle gasholder-tank for the Bournemouth Gas Company in the worst possible soil, viz., running sand, for a gasholder not much more than half that size, for about the same price per thousand cubic feet; which, bearing in mind the bad ground in which the tank had had to be constructed, and that the smaller the tank the more it should cost per thousand cubic feet, seemed to show that tanks of the brick-and-puddle class, if built in satisfactory soil, such as clay, should be constructed at a much less cost than that named by the Author. He had designed a concrete tank as an alternative, but the cost would have been greater. In 1897, when bricks were very dear, he had constructed a concrete-and-puddle tank in clay soil for a holder of 1 million cubic feet capacity. The concrete had been made of burnt ballast, the clay as it was excavated from the trench having been burnt into ballast and then returned in the form of concrete to make the wall. There had been considerable difficulty in disposing of the excavated material, and hence it had been desirable to use as much of it as possible in the construction of the tank. The burnt clay ballast and puddle disposed of a great deal. This was probably the first gasholder-tank ever constructed of concrete made with burnt ballast. There had been a slight leak at first, due, he thought, to a fault in the puddle at the inlet- and outlet-pipes, but it had since "made up" and the tank was now perfectly sound. The cost had been £3 17*s.* per thousand cubic feet capacity, which, considering the small size, could not be considered dear. In passing, it might be noted that it was perhaps scarcely fair, when comparing the costs of different tanks, to base the cost upon the cubic capacity of the gasholder, because a three- or four-lift holder required no larger tank than a single or two-lift holder of the same diameter. The tank would cost the same in either case, if of the same diameter and depth. The comparison would be better made in terms of the capacity of one lift of the holder.

Mr. Cripps.

The Author's designs for the guide-framing of gasholders were light and strong, and had an excellent appearance. They were constructed on the same principle as Mr. Livesey's gigantic holders at the South Metropolitan Gasworks, viz., the whole of the guide-framing was braced together so as to form one large vertical cantilever instead of a number of practically independent posts. This system had been first introduced by Mr. George Livesey in the 5½ million cubic feet holder at the Old Kent Road Works, and had since been very generally adopted for large holders, and in a measure for small ones. Needless to say, Mr. Livesey's six-lift holder of 12 million cubic feet capacity, at East Greenwich, was constructed on this principle. The principal departures from ordinary practice observable in the Author's designs were: (1) Substituting double the number of light and shallow standards for the usual heavier and deeper ones; (2) the abolition of piers outside the tank-wall to carry the standards; (3) the abolition of holding-down bolts, setting the foot of each standard in the solid concrete instead. As regarded (1), although the construction of the guide-framing on the joist system was remarkably simple and cheap, he could not help thinking that a well-designed holder of the lattice-standard type could still be made almost as cheaply, if not more so. For if the number of standards, girders and guides were doubled, so were all the top and grip carriages and rollers doubled in number, and these formed rather an expensive item. Comparing the cost of holders of the lattice-standard type with those mentioned by the Author, he found that a holder erected to his designs on the south coast had cost £4 17*s.* 8*d.* per thousand cubic feet capacity as against the £4 18*s.* 1*d.* per thousand cubic feet for the holder of the same capacity on the joist system as given by the Author. He had designed another of about 1 million cubic feet capacity (the nearest in size to the other example quoted by the Author), which had cost £5 5*s.* 7*d.* (or £5 10*s.* 4*d.* including the trussed top) per thousand cubic feet, as against £6 13*s.* 0*d.* per thousand cubic feet given in the Paper as the cost of a holder of ¾ million cubic feet capacity with the plain joist type of guide-framing. But to get an exact comparison, the prices of iron should be taken into consideration at the respective dates when the holders were erected. It seemed to show, however, that there was still something to be said for the framed standards, and for their being put as wide apart as the ordinary conditions would permit. (2) To abolish the piers tended to considerable economy, as it reduced and simplified the excavation, timbering, labour and materials. He

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Mr. Cripps. had for some years past partly abolished the piers in concrete tanks—that was, the piers had only extended down the walls a sufficient distance to enclose the holding-down bolts, and he had made the holding-down bolts shorter than had formerly been the case. The piers were tapered off slightly at the bottom, and hooking-irons were embedded in the concrete to further strengthen the union of the projecting pier with the wall. He had no doubt whatever that but for the slight risk of cracking the wall or its skin, very short holding-down bolts indeed would suffice in a properly braced structure. In any case, the two back bolts could be quite short and could have a shallow pier where the depth from front to back of the standard exceeded the thickness of the wall, the front bolts being taken down much lower than the back bolts so as to grasp a considerable weight of wall and avoid the risk of cracking it. (3) With regard to letting the foot of the standards into the tank-wall, it would appear that a very slight movement in the standard, due to temperature, wind, vibration, etc., might lead to a small fracture of the concrete which, in the case of a rendered tank, would be sufficient to make it leak. As the standard was let in but a very short distance, the leverage over the part of the wall which it grasped was considerable. On the other hand, the usual holding-down bolts did not strain the tank at the top, but at a level many feet below, where it was better able to resist it. But in a puddled tank, so far as watertightness was concerned, this objection would not apply. The weight of the 18 inches extra length of standard would scarcely be less than that of the usual holding-down bolts and plates; but a good deal of trouble and expense was saved in fixing, the usual long holding-down bolts being very troublesome things to fix properly.

As to the general construction of gasholders, the Author alluded to the importance of making the tank-guides and standard-guides in line with each other. Violations of this simple rule were so frequently met with that it was well to emphasize it. Not long ago he had been called upon to design a new lift for an existing holder. The more he had examined the existing structure, the more imperfect it had appeared. Not only had the tank- and standard-guides been put one in advance of the other, but the roller carriages on the two existing lifts strained their necks up as high as possible instead of nestling down as low as possible. The cheeks of the grip-carriage had been actually forged on the top ends of enormously strong angle-bars, which formed outside stiffeners running to the bottom of the outer lift. Each of the guides in the outer lift consisted of a channel-bar and two angle-bars, which,

together with the outside stiffeners, formed a framing about three times as heavy and as strong as should be put in a holder of three times the capacity. While there was this preponderance of strength here, there were weak spots in the design in other ways. For instance, the cup was only 14 inches deep, whereas no telescopic gasholder should have the cup less than 18 inches in depth, or it would be liable to blow in uncupping. The crown had strips of strong plates radiating from the centre to the curb, the intermediate space between the strips being filled up with light sheets, under the delusion that the strong strips strengthened the top, forgetting that the stress on a sphere or segment of a sphere was uniform throughout, and therefore the thickness of the sheeting should be uniform throughout. Radial strips only prevented the top from ballooning out under the pressure and caused severe local strains. The top had a rise of at least double as much as it need have had if it had been of a uniform thickness, thus wasting gas-space by always imprisoning so much more dead gas. If the guides had been linable, and the construction had been at all usual, when the new lift had come to be added, all that would have been necessary would have been to put the grip rollers on the outer lift on the side of the grip, and thus lower all the carriages snugly. But, on the contrary, everything had been rendered difficult and expensive by want of forethought in the original design. It therefore seemed desirable that practical engineers should from time to time draw attention to even the simplest principles in design, to prevent, if possible, such wasteful structures. Mr. Cripps

He wished to put in a small plea for gasholders with trussed crowns. In very many cases (more particularly where the holder was shallow for its diameter) it was found that the top lift of an untrussed holder did not give sufficient pressure of gas, and suggestions were sometimes made to add weights to it, so as to increase the pressure; but if, instead of spending money on the frame in the tank, the same or less money were spent on a framing in the crown, this difficulty of pressure would seldom arise. Of course there was a practical limit to trussed crowns, but any holder up to 175 feet in diameter could be trussed without much difficulty, if the pressure to be given by the inner lift rendered it desirable; and even for such a size, the cost would not differ greatly from that of a separate frame in the tank. The extra pressure of course was thrown back on the works. Purifier lutes, siphons, etc., had to meet this, as well as the exhausters, but the extra fuel required to drive the exhausters was very trifling. He

Mr. Cripps. therefore thought there was still something to be said for a trussed top. Cases might be mentioned where, if the tops of the holders had been trussed, much expense might have been saved. A special fan had to be fixed to get the gas away with sufficient pressure, because the top lifts were so light that they did not give enough pressure. This probably involved the use of more fuel than if the exhausters had done the work at first, besides other expenses.

The Author adopted elevated purifiers discharging from the bottom, but in the matter of discharge-pipes Mr. Cripps thought a better type was that made in segments corresponding with the depth of each tier of sieves, each segment being lifted out in turn as the sieves were removed. This allowed of the material being thrown into the discharge-pipe without any lifting. Purifiers without water-lutes for the covers were becoming very general, but he believed the Author had been the first to design the cover of the same size as the purifier, when of the non-luted type, instead of a number of what he termed "mere manlids." The Author's system of holding covers down in the central area was a great advance on the old-fashioned plan of throwing all the lifting-stress on the edges of the purifier, and allowed of the covers being made much lighter, besides reducing the strain on the side-plates of the purifier and on the curb of the cover. Also, the lift at the edges being reduced, the soundness of the joint was more secure. It had been found in practice that the lifting-pressure on the cover in a large purifier might be sufficient to raise the sides of the purifier right off the foundations,[1] but by holding down the cover in the central area as well as the edges this danger was avoided. In purifiers without water-lutes the pressures might rise considerably, in fact until the siphons belonging to the apparatus preceding the purifiers began to blow; and therefore the lifting of the side-plates must be guarded against, and the whole purifier must be designed to resist the extra stress that might come upon it. The central holding-down was undoubtedly a great relief. The standards for sieve-bearers could easily be made use of for anchoring the holding-down bolts for the cover. In designing covers to resist high pressures, curved surfaces should be adopted where practicable and not flat surfaces, otherwise the stress was so severe on the sheeting and riveted joints. Doubtless covers with flat tops might be pointed to as having stood successfully, but it was probable that no very great

[1] "...ains in Large Purifiers," by F. S. Cripps. London: Walter King.

pressure had ever come upon them. If they were tested under pressure up to 36 inches head of water or more, they would probably show signs of weakness. Mr. Cripps.

Mr. PERCY GRIFFITH felt that many engineers, equally with himself, would highly appreciate the Author's valuable Paper on the present-day condition of the gas-industry. The Author contended that the greatest permanent saving was to be attained in the limitation of capital expenditure; but Mr. Griffith considered that in stating that, where conditions were not too unfavourable, works, mains, meters and working-capital could be provided for between £400 and £500 per million cubic feet, for an output of 50 million cubic feet per annum and upwards, the Author had carried his argument somewhat farther than was justified by common experience, and had ventured to make a statement which, without important qualification, must be considered misleading. Although this figure worked out in the case of the Author's own works (1899) to £416 per million cubic feet, in the case of the South Metropolitan Gas Company to £425 per million cubic feet (as converted), and in the case of the Wandsworth Gas Company (where the Author's son was in charge) to £366 per million cubic feet, it should be observed that the average of the three largest London companies was no less than £550 per million cubic feet of output, and that of the twelve suburban companies was £558 per million cubic feet: it was therefore fair to assume that the extremely low figures suggested by the Author were due to some peculiar and exceptional circumstances. With regard to smaller works, however, where there was less facility or excuse for the expenditure of capital on elaborate and expensive improvements in manufacturing-plant, the figures given by the Author were totally inapplicable, and as the Paper was not specifically limited to large undertakings, he thought that some special notice might have been taken of conditions which affected the larger number of works if not the most important of them. From the Board of Trade returns it would be seen that the capital employed in the smaller undertakings averaged well over £1,000 per million cubic feet of gas sold per annum, and it was obvious that in these cases the charges for dividend and interest were by no means fatal to successful working. In a case within his own experience a gas-company had been recently floated with a capital of over £2,500 per million cubic feet sold during the following year, and owing to rapid development of the business it had been able to earn a dividend of nearly 4 per cent. on this enormous capital, while the price charged for gas did not exceed 4*s.* 6*d.* per thousand cubic Mr. Griffith.

Mr. Griffith. feet. In another case upon which he had had the benefit of the Author's advice with regard to the design of new works, the present capital, recently converted to a 5 per cent. basis, and including capital on account of an abandoned works not yet written off, amounted to over £2,000 per million cubic feet sold (22 million cubic feet in 1900), and a dividend of 4 per cent. had been earned and paid. In this case the works were arranged with a view to economical extension, the demand for gas increasing at a rate of between 15 per cent. and 20 per cent. per annum, so that each year, apart from anything written off on account of abandoned works, the proportion of capital would rapidly diminish. The instances above quoted, however, proved that the very low capital ratio suggested by the Author must not be considered as applicable to all cases, particularly to small works. Another important factor in connection with the capital ratio, to which the Author made no reference, was the condition of the works relative to the existing demand for gas and its yearly increment. A works, like the second case mentioned above, where land, sidings, buildings, and mains were provided of a capacity far in advance of immediate requirements, must of necessity involve a temporarily high capital ratio, and in all cases where the annual increase in the sale of gas had amounted to more than 10 per cent. over a long period, the provision of land, buildings, and mains, if not of actual plant and storage, well in advance of immediate requirements must be admitted to be both necessary and expedient. Whilst diffident about criticising the opinions of such an experienced gas-engineer as the Author, he felt justified therefore in stating his opinion that the value of the capital-ratio as an estimate of the efficiency of any particular undertaking was worth little unless other factors were considered in conjunction with it. The argument that any capital outlay which in itself was permanently remunerative must obviously be justified was also one to which no reasonable exception could be taken.

Mr. Humphrys. Mr. N. H. HUMPHRYS remarked that the Paper was on the whole a fair and accurate presentment of an extensive subject, the magnitude and recent rapid growth of which were well represented by the extracts from the Board of Trade returns quoted at page 46. Whilst not wishing to detract from the weight of the three departures referred to in the introduction, he ventured to suggest that an important item in connection with the increase in the demand for gas during the last few years had been the adoption of a more advanced and enterprising attitude on the part of gas-companies towards their customers. This action had been greatly

assisted by the incandescent burner and the coin-meter. Up to a comparatively recent date the average gas-company had considered that its duties and responsibilities ended at the consumer's meter. If gas of good quality were delivered at that point, at the lowest possible price, it had been assumed that the commodity would advertise itself, and the attention of the gasworks manager and his staff had been concentrated upon minor economies in manufacture and purification, while the consumer had been left to blunder along as best he could. In the light of present-day experience it might be questioned whether the hobby of cheap gas had not been ridden too hard, and whether better results would not have followed, in regard to the interests of both consumer and producer, if the policy now generally recognised as correct had been adopted at an earlier stage. The sliding-scale legislation had tended to concentrate attention upon the question of price to the exclusion of more important matters; for a consumer supplied with gas at 2*s.* 0*d.* per 1,000 cubic feet, which he used by means of appliances put down by a gasfitter who might be a competent plumber but had no knowledge of the properties of gas, might be worse off than another who paid perhaps 3*s.* 0*d.* per 1,000 cubic feet, but had had the benefit of thoroughly competent assistance as regards the whole outfit from meter to burner, from the gasworks staff. Another objection to the sliding scale was the fact that, being attended by the auction clauses, the rates of dividend were nominal only, and always considerably higher than the actual return on the investment. The "man in the street" reading that a gas-company had declared a dividend of 15 per cent., at once concluded that the holder of £100 capital had received £15, and abused the rapacity of the gas-companies to that tune. Whereas the fact was that the holder of £100 scrip had really paid for it, and the company had received, over £300 under the auction clauses, and the company paid, and the holder received, something under 5 per cent. The necessity for doing away with nominal dividends, at two or three times the rate actually received, had become apparent, and many companies had met the difficulty by increasing the nominal value of the capital, reducing the nominal dividend in a corresponding degree. For the first lesson to the effect that cheap gas and high dividends, though worthy objects in their way, were not the sole end and object of a gas-company's existence, some credit was due to the manufacturers of gas cooking-stoves. When these gentlemen had come forward and been willing to take the main share in the trouble and expense of promoting exhibitions of gas-appliances and cookery-demonstrations, some of the young

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and reckless gas-companies had actually peeped out of their shells, shaken hands with their customers, and gone to look at the state of things on the consumers' side. Some of the old and cautious companies had shaken their heads and said that sort of thing was not in the Act of Parliament, but the unmistakable success of these ventures, and the reception accorded to them by the consumers, could not be gainsaid, and it had soon become evident that a show-room was a necessary auxiliary to every gas-office. And now it was no uncommon thing to find the gas-company undertaking anything and everything that the user of gas required. In any case the old isolation was completely broken down and the requirements of the consumer were assisted in various ways. As soon as gas-companies changed their attitude the demand for gas had increased; and with this progress in view it might reasonably be hoped that gas-companies would eventually attach as much importance to the selling department as was usual with other manufacturers. The incandescent-mantle gas-burner had made great progress, but not in a degree commensurate with its intrinsic capabilities, or the truly marvellous nature of the discoveries of Auer von Welsbach, which at one stroke had multiplied the actual illuminating-value of the gas to the consumer not less than sixfold. And in considering the aggregate increase in the quantity of gas consumed, the fact that many users, whilst getting more light, had largely reduced the actual quantity of gas used should not be overlooked. It was unnecessary to discuss in detail the causes which had hampered the extension of this system. In the first place, however, it was an unregulated monopoly, and as such the appliance was sold at a high price. Even after large reductions the cost was still much higher in England than on the Continent. At first the proprietors had endeavoured to introduce it independently of gas-companies, by means of a special agent in every town or district, and although this had been altered, and gas-companies were now put on the same footing as other wholesale users, a good deal of unnecessary friction was caused by regulations of an autocratic character, some of which restricted the sale as much as they protected it. The appliance was continually before the law-courts, and the advertisement columns of newspapers and magazines teemed with threats of all the unknown terrors of the law against everybody and anybody who might by accident or intention get within striking distance of an infringing imitation. As a consequence many prospective customers, having no practical knowledge of the difference between the genuine and the spurious article, preferred to be cautious and to have nothing to do with it. If the enormous sums which had

been expended on legal and advertising processes had been devoted to cheapening the article itself, there would have been no room for imitators to work at a profit, and the incandescent mantle would by this time have been more generally used than the flat-flame system. The enormous demand for coin-meters in London and elsewhere was due to the fact that their introduction had been made an opportunity for meeting the wants of that large section of the public which was not prepared to spend a quarter's or a half-year's house-rent in piping and fitting up for gas a tenement in which they had no permanent interest, by putting in everything required on inclusive terms, so that there was no initial cost or liability beyond the insertion of coins in the meter from time to time as required. In towns where the gas-company, though willing to supply slot-meters, fixed them on the same terms as ordinary meters, and did not furnish appliances on hire, but left the tenant to supply them in the usual way, there was scarcely a larger demand for coin-meters than for ordinary meters. Whilst not overlooking the fact that the coin-meter was a special attraction, he submitted that it was not entitled to the sole credit of the large increase of consumption which had followed its introduction. In many cases the saving of coke rendered possible by the improvements indicated in the Paper had been largely discounted by the practice of disposing of the so-called surplus at a nominal price to anyone who would take it away; and instances were on record of the coke market at A having been weakened by surplus coke brought from B, while on the other hand that at B had been spoiled by a surplus brought from A. When this mischievous policy, which in the end created a weak market all round, was replaced by an energetic and enterprising attitude in regard to local business, the returns for coke would be enhanced to a greater degree than in the past. Unless exceptional conditions existed, the people who used the gas would also use the coke, provided their requirements as to quantity, delivery, size of lumps, and other conditions received adequate and competent consideration. As to tar, it was remarkable that gas-companies did not benefit in the slightest by the large additions to the valuable stuffs extracted from it, and that the market price of tar had decreased rather than increased. Notwithstanding all its wonderful constituents, a man who wanted to tar a fence would pay more for it than the chemical manufacturers offered. As to capital expenditure, he thought that the hobby of low capital, like that of cheap gas, might be ridden too hard. He was no advocate for extravagant expenditure, and the undertakings noted for supplying cheap gas,

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Mr. Humphrys. while exercising due economy in outlay, did not allow the efficiency of their plant to suffer, but were well equipped as regarded their requirements, and could, when occasion demanded, undertake extensions with no sparing hand. Capital bloated by extravagant and unnecessary outlay, or by the purchase of badly-designed and inefficient plant, was undoubtedly a cause of dear gas. But it was also possible to quote cases of small capital and high prices. The low charge for interest on capital was more than covered by high working-expenses due to the use of old-fashioned, cheap, and inefficient apparatus, and especially by forcing the capacity of a plant beyond the proper limit. No doubt it was a wise policy to keep down the capital, but it was well to remember that this only applied to unnecessary or wasteful expenditure. Money could be wasted just as effectually by refusing necessary outlay as by going to the other extreme. In regard to distribution, the increasing demand for gas must eventually lead to the use of much higher pressures than were usual at present, and there was no reason whatever why gas-distributing systems should not be rendered sound and safe under pressures that would be measured in feet of head of water instead of in tenths of an inch. Natural gas had been distributed for years in America under a pressure of 50 lbs. per square inch or more, and no difficulty had been experienced in reducing this pressure, at the entrance to the consumers' premises, to that usual for the supply of artificial gas. A safety device was used which entirely precluded the possibility of the high-pressure gas passing on to the internal fittings. In these days of 20-ton steam-rollers, gas-mains of water-main section and steam-tubing for services were indispensable, and as for this reason alone a distributing-system capable of withstanding a comparatively high pressure must be provided, it seemed absurd to restrict the supply-pressure to a few ounces per square inch.

Mr. Hunt. Mr. CHARLES HUNT remarked that the Paper was an able summary of the present position of the subject, but exceptions to it might be fairly taken. With what the Author had said about the Welsbach burner, and its influence upon the development of gas-consumption, it was impossible not to agree. He also agreed that the introduction of the coin-meter had largely helped to consolidate the position of gas-supply. The Author did not appear, however, to quite realize the position of municipal undertakings in relation to it, in saying that this system of supply conformed to "modern municipal aims." He would find upon inquiry that the largest municipal undertakings were compara-

tively small customers for coin-meters, but he would not be justified in inferring from this that the management of these was or had been regardless of modern municipal aims, the fact being that, long before the introduction of the coin-meter, gas was, under municipal management, being largely used by all classes of consumers. This applied in particular to such places as Glasgow, Leeds and Bradford, while in Birmingham, where the coin-meter was being used more largely, although not nearly to so large an extent as by the companies quoted by the Author, the average consumption per meter was not much more than one-half the average consumption per meter in the Metropolis. It might be fairly inferred from this that by means of the coin-meter a poorer class of customers was being reached in Birmingham than in London. Incidentally it might be mentioned that its introduction had been due largely to the initiative of a company working under the old legislation, namely, the Liverpool Gas Company, which had always had a reputation for safe and conservative management. This gave point to his suggestion that the companies had much more leeway to make up in the extension of their business than had the municipalities owning gas-undertakings. He was unable to agree that the sliding scale had had any appreciable effect in stimulating to improved methods of manufacture. He believed in the sliding scale, because it appeared to him that the reward of the shareholders should be proportionate to good management; but the sliding scale was of itself powerless to convert indifferent into good management. The absorption in 1882 or 1883 by the Gas Light and Coke Company of the late London Gas Light Company had removed the last chance of comparing the results of the new legislation with those of the old. There was reason to believe that had that Company continued its separate existence under the old conditions, it would have had to supply gas at a cheaper rate than its neighbours, either south or north of the Thames, because of its low capital charges. The Author appeared to attribute the introduction of labour-saving appliances to the indirect influence of the sliding scale; but he could not intend to suggest—although this might be reasonably inferred from the statements in the Paper—that but for the sliding scale the London companies would not have availed themselves, for example, of Hone's invention for cheaply and expeditiously unloading their coal-barges. Also, with regard to stoking-machinery for charging and discharging retorts, which, unlike Hone's invention, was essentially a gasworks appliance, the system most in use at the present day was the

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Mr. Hunt. invention of the engineer of a non-sliding-scale company, who had been rewarded by the post of chief engineer to one of the largest municipal gas-undertakings. Manchester had employed stoking-machinery since the seventies, and one of the first efforts of the Birmingham Corporation after obtaining possession of the gasworks had been to introduce this machinery, which had been largely used by them since about the year 1883. What was the Author's own position in relation to this matter? His company had accepted the sliding scale in 1875. When had he adopted stoking-machinery? Had he done so before 1896 or 1897, fully 20 years afterwards? And was not the system the Author had applied mainly the invention of a municipal gas-engineer, Mr. William Foulis, M. Inst. C.E., of Glasgow, at whose works it had been in extensive use for some years previously? Neither at Glasgow, Manchester, nor Birmingham could the introduction of stoking-machinery have been in the slightest degree influenced by the sliding scale, and Mr. Hunt asserted, without fear of contradiction, that these three municipalities had taken a foremost part in the introduction of labour-saving gasworks-appliances. The Author referred in the Paper to various arrangements which had been devised by himself and others to "avoid the cost of fixed elevators and overhead construction, and further to enable the coal to be taken direct from the stores to the retorts, saving removal to fixed points, followed by transfer to the machine"; but he had omitted to point out that such arrangements could be admissible only where, as in London, the coal used was generally so fine as not to require to be passed through a coal-breaker. In the Midlands it was only here and there that such a supply could be obtained, the fine coal being in demand for making hard coke. Except in the case of nuts, the quantity of which was limited, all coal used in the Midlands had to be passed through a breaker, which it was obviously impossible to move about. Another instance of what he might perhaps be permitted to term "local colour" appeared at p. 58, where, referring to an objection to the use of inclined retorts, which originated in London, the Author stated that this objection must be absolutely overcome before the system could make much headway. It seemed only necessary to observe that, notwithstanding the objection to which the Author referred, the system of inclined retorts was making remarkable headway. Germany had practically made up its mind on the subject, and everywhere in that country inclined retorts were the order of the day. Birmingham, Coventry, Manchester, Salford, Leeds and Edinburgh, as well as Nottingham, Huddersfield,

Burnley, and other places almost too numerous to mention, had all adopted inclined retorts. What, too, was of the greatest significance was that the most recent extensions were the largest. In Birmingham a plant having a capacity of 5 million cubic feet had been started to work last October, and the erection of another large plant had been commenced; while in Edinburgh entirely new and very large works on this system were in progress. How, then, was it possible to accept the Author's dictum, except perhaps as applicable to a somewhat limited metropolitan area? The Author's Table at p. 50 was scarcely convincing as to the advantage derived by undertakings not requiring or using enrichment. Enrichment (except by means of cannel) saved labour, and therefore the labour-bills should be compared, as well as the returns for residuals; moreover, immediately afterwards the Author referred to carburetted water-gas as a cheap enricher, and his figures showed it to be cheaper, candle for candle, than ordinary coal-gas. He did not understand why, in this connection, the Author should refer to carbonic acid as an impurity, since its removal from carburetted water-gas was simply a question of comparative cost. Its presence caused a diminution of illuminating-power, which could be made up by using more oil, and the balance had therefore to be struck between the cost of this additional amount of oil and that of removing the carbonic acid by means of lime. According to his experience, it would be cheaper to use additional oil at about 3*d.* per gallon; but with oil at its present price (or at the price ruling during the past year) it would probably pay better to remove the carbonic acid. His experience of naphthalene deposits and water-gas did not confirm that of the Author, for, so far, no benefit had been experienced from the use of the latter in the removal of these deposits. Nor was he at one with the Author as to the superior efficiency of the horizontal condenser for promoting contact with the gas and its tar, although he was disposed to agree that the latter was capable of removing the whole of the naphthalene from the gas. For this, however, temperature was an all-important factor. In the Paper[1] which he had had the honour of presenting to the Institution in 1894, he had been able to show in diagrammatic form the results of three years' experience, in which the number of cases of deposit rose and fell according to the temperature at the outlet of the condensers, being greatest where the temperature was highest, and gradually diminishing to total disappearance when the temperature settled down to a maxi-

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[1] Minutes of Proceedings Inst. C.E., vol. cxvii. p. 208.

Mr. Hunt. mum of between 50° and 55° F. From this he had inferred that whatever might be the form of the condenser, if means could be found to reduce the gas-temperature during the hottest months to something below 60°, naphthalene deposits might almost be made to disappear throughout the year, instead of only during the seven or eight coldest months. At the same time he had been and he still was of opinion that the proper remedy for naphthalene deposits was to be applied in the retort-house, since they were not an indication of good carbonizing, but rather the reverse. Crude, or "straight" water-gas had a heating-value of about 280 B.T.U., that of 16 candle-power gas being about 600 B.T.U. The Author's statement that the former would be for all purposes as useful to the consumers as the latter, and even more valuable for heating-purposes, seemed to require some elucidation. With regard to the mention by the Author of the "Siemens regenerative furnace," he might point out that the continuous recuperative furnaces which were now so generally employed for heating retorts were not the invention of any of the Siemens family, although they were of German origin. Continuous recuperation, in fact, dated from long before Siemens' time. In 1847 Richard Laming, whose name was well known to a former generation of gas-makers, took out a patent for heating gas-retorts by means of a continuous recuperator made of iron tubes, which patent described a method of checking the primary air-supply so as to generate carbonic oxide, and the introduction of a secondary air-supply, upon the same lines as were now followed in the various systems of regenerative firing. This invention was not at that time a new one, for subsequently Mr. Laming filed a disclaimer of that part of his patent on the ground of want of novelty. In more recent times the Ponsard gas-furnace was the first example of continuous recuperation by means of recuperators built of firebrick, and it was probably the success of this furnace which had suggested to German engineers the possibility of heating gas-retorts in a similar way. With reference to the Author's observation on the construction of gas-tanks, it might be observed that it did happen that there were places where material for concrete was not easily obtained in large quantities, and where at the same time bricks of excellent quality, much superior to London "stocks," could be obtained at a reasonable price. Such a place was Birmingham, where, in consequence, there were no concrete tanks. With concrete at 17*s.* per cubic yard, and brickwork at about 21*s.* per cubic yard, as compared with 10*s.* and 25*s.* quoted by the Author, there was much aid in favour of the method of construction advocated

in the Paper. There were probably, however, but few places where cement rendering was not more economical than puddle, and, on the whole, more satisfactory to employ. When referring to gas-holders, the Author made no mention of the introduction within the last few years of columnless holders, nor of the abandonment by Mr. George Livesey of guide-framing for the inner lift. He noticed with some surprise the Author's deprecation of the use of 2-inch gas-mains for distribution, not because he advocated their employment, but because he had supposed that they were obsolete, except in connection with small gas-undertakings. In Birmingham scarcely any gas-mains smaller than 4 inches in diameter had been used for fully a quarter of a century, and for some time past a large number of 6-inch mains had been used where, a few years ago, 4-inch mains would have been considered sufficient. For the same length of time "steam" service pipes had also been in use, up to and including 1¼-inch diameter, the weight and thickness required being, however, specified. This was necessary because some sizes of steam-pipe were now no thicker than had been the same sizes in gas strength some years ago, the listed thicknesses having been reduced. The Author's observation as to the practical supersession of the wet meter did not apply to Birmingham, where wet meters continued to be employed exclusively. Mr. Hunt.

Mr. Walter Hunter considered that the Paper formed a useful and valuable addendum to the Papers which the Author read in 1875 and in 1880. It was of special value to the directors and engineers of gas-companies in laying down the general principles upon which expenditure of capital for gas- and similar undertakings should be based. One of the most important parts of the Paper was that in which the Author showed the vital importance of economy in capital expenditure, and pointed out that the undertakings supplying cheap gas were those with relatively small capitals. The Author modestly refrained from naming instances, but as Deputy Chairman of the Commercial Gas Company, Mr. Hunter desired to point out that the two Metropolitan undertakings for the management of which the Author had been mainly responsible, the Commercial and Wandsworth Companies, possessed the distinction of having the lowest capital, per 1,000 cubic feet of gas sold, of any of the Metropolitan companies. The net profit per cent. on the capital was generally largest, as might be expected, in the case of the companies possessing the lowest capital. This would be seen from the following figures, extracted from Mr. Field's "Analysis" for the year 1899:— Mr. Hunter.

r. Hunter.

——	Capital per 1,000 Cubic Feet.	Net Profit per Cent. on Capital.
	s. d.	
Wandsworth Gas Company	7 4	9·59
Commercial „ „	8 4	12·25
South Metropolitan „	8 6	10·01
Crystal Palace „	9 3	8·16
Gas Light and Coke Company	12 5	10·63
West Kent Gas Company	16 0	13·46
Bromley Gas Company	17 11	8·46
Lee Bridge Gas Company	19 7	6·37

The position of the West Kent Gas Company was exceptional, owing to the high price which it had power to charge. The large capital expenditure of some of the above-mentioned companies might be due to special circumstances, but this did not affect the general argument. He further desired to point out the excellent results in regard to purification achieved by the Commercial Gas Company under the Author's management. The official returns of the three Metropolitan Companies for sulphur and ammonia per 100 cubic feet during the year ended 30th July, 1900, were :—

——	Sulphur.	Ammonia.
	Grains.	Grain.
Gas Light and Coke Company	11·1	0·4
South Metropolitan „	12·9	0·6
Commercial Company	8·3	0·2

One effect of the introduction of electric light had been to stimulate a demand for more light, and it had consequently, in his opinion, tended to increase the consumption of gas. On the other hand, the powerful electric arc-lights seemed at one time to put gas out of competition for street-lighting, except in regard to cheapness of production. The Welsbach burner, however, had restored the equality, and, taking cost into consideration, the supremacy of gas. This result had been still further developed by the introduction of burners using gas under high pressure. The finest installation of street-lighting under the high-pressure system which he had seen was that in the Rue de la Paix, Paris. In London similar good results were being obtained. If the lighting of Parliament Street and Whitehall by high-pressure gas ared with the lighting of the Thames Embankment by

electricity, it would be seen that the former was far more satisfactory, while it was much less expensive. For out-door illumination there could be no doubt that the cheaper light ought to be used. Unfortunately, during the past few years there had been a craze on the part of municipal authorities to possess electric-lighting installations of their own. This policy had resulted in unfair competition with the gas-companies, owing to the tendency of public bodies to supply electric light at a price below its cost, with a view of driving gas out of the field, the balance of the cost being made up out of the general rates. This policy might be satisfactory to the consumers of electric light, but it was inimical to the general interest of the public, who thereby were caused to pay additional rates to cheapen the cost of electricity to the private consumer. The introduction of the coin-meter had largely increased the field of gas-supply. On the 31st December, 1900, the number of ordinary consumers in the Commercial Gas Company's district amounted to 23,989, and the number of consumers supplied through coin-meters to 13,017. The coin-meter was undoubtedly a great boon to the industrial community, especially in conjunction with cooking-stoves, which enabled cooking to be effected at very small expense and with great cleanliness. The important effect of the introduction of the coin-meter in increasing the number of the consumers would be seen from the above figures, while, as pointed out by the Author, the system further possessed the advantage of causing a largely increased consumption of gas during the day, and so keeping the plant more continuously at work. The experience of the Commercial Gas Company, in regard to carburetted water-gas, proved that it was of great value as an adjunct to a gasworks, for the reasons shown clearly in the Paper. In conclusion, he desired to point out that labour-saving machines were of no use unless they resulted in the cheapening of the article produced, or in doing away with operations which were deleterious to health and caused undue wear and tear upon human life. Mr. Hunter.

Mr. Wm. R. Hutton observed, in reference to the condition of the gas-industry in New York City, that the threatened competition of the Edison Electric Illuminating Company, the Electric Light and Power Company and others had been deemed of sufficient importance to induce the Consolidated Gas Company to purchase outright these and the smaller companies. Within the past 2 years four smaller but rival gas-companies had been combined with the larger company, itself a very profitable consolidation made some Mr. Hutton.

Mr. Hutton. 15 years ago of all the then existing companies. The consumption of gas at the present time was about 25,000 million cubic feet yearly for the consolidated gas-companies in New York, and for the Brooklyn Gas Company, recently added to the combination, about 4,400 million cubic feet, together supplying a population of about 3,500,000. Of this about one-fourth was coal-gas; the remainder was carburetted water-gas, which would probably supersede entirely the coal-gas in the works of these companies. The works were situated almost entirely in the thickly built portions of the city, covering large areas of very valuable land. In order to realize this property, a tract of land had been purchased on Long Island Sound, adjoining Brooklyn, and land had been acquired later in New Jersey on the opposite side of the Hudson River. It was rumoured at present that the latter site would be adopted for the construction of works of sufficient magnitude to supply at least that portion of the greater city west of the East River, the gas being brought by pipes in one or more tunnels under the North or Hudson River. Both sites were easily accessible by water. Mechanical appliances were used for charging and drawing the retorts, &c. All the modern gas-tanks were of steel, built upon foundations of concrete and piles (where the latter were required) at a greater or less depth below the surface of the ground, contact with the earth being prevented by a walled area from the foundation. They were made watertight by a bottom or floor of light plates of steel. The soil at the various sites of the tanks in New York was not such as to permit of their construction in masonry or concrete. The recent tanks had been about 175 feet or 180 feet in diameter, with a depth of water of 40 feet to 45 feet. These dimensions involved the use of very heavy plates for the lower courses, plates up to $1\frac{1}{4}$ inch in thickness having been used. The inconvenience and expense of drilling and handling these heavy plates had induced the Continental works, which had built a number of these tanks, to adopt a system of double plates, using two plates $\frac{7}{8}$ inch thick for the lower courses, diminishing to $\frac{7}{16}$ inch in thickness at mid-height of the tank. Not only could the thinner plates be more easily handled and punched, but they could be obtained in greater lengths than the very thick plates. Those of the Nineteenth Street tank were 25 feet long, reaching from buttress to buttress, and 4 feet 6 inches wide. Although in some of the tanks the guide-frames were carried by brackets reaching down some distance (say 12 feet to 16 feet) on the shell, in this tank they were carried by buttresses, 3 feet wide, resting on the foundation. These, in connection with the circular girder at the

top of the tank, formed a rigid frame, and in one case had been of great utility. The pile foundation having settled, very slightly but unevenly, they had afforded points for the application of hydraulic jacks to restore the tank to position. The guides, twenty-two in number, were braced with flat bars, riveted to the verticals as described by the Author. The gasholders were generally of three, sometimes of four lifts. In one instance the upper holder rose entirely above the guide-frame, an arrangement which seemed to answer well. In the more recent holders the trussing of the roof was omitted. The distributing systems of both gas and water in the city of New York, owing to its gradual though rapid development and the number of gas-companies having the right to lay pipes in the same streets, had produced a result of great complexity. Some of the streets were so filled with pipes, in use or abandoned, that there was no room to lay an additional main. When an increased service was demanded it could be obtained not by laying other mains, but by replacing those in use by larger mains. Electric subways had in recent years come in to add to the confusion. The mains were generally of cast-iron of considerable thickness, which was rendered necessary by the rough handling in the frequent opening of the street to lay sewers, electric subways, and at present for the construction of the rapid-transit tunnels. Wrought-iron pipes had been used to some extent, and were found to be satisfactory. Electrolysis, which at one time had done much damage, especially in the borough of Brooklyn, had been to a large extent eliminated by the use of better return-conductors. All the electric lines in the borough of Manhattan (old New York City) were on the so-called sub-trolley system, the conductors being placed in conduits under the roadway. Mr. Hutton.

The Author, replying to the Correspondence, thought Mr. Botley would find that he could not maintain such conditions of purity as were necessary in London, by using scrubbers without coke, or those filled with 3-inch drain-pipes. On the question of naphthalene deposits, he had given the results of 20 years' continuous experience of a gasworks (Epsom), which was too stubborn a fact to be overthrown by any opinion. As to the omission of the guide-framing for the upper lift of a gasholder, he could only approve such an omission where the lower rows of standards and trussing were so strong as to be able to maintain the weight of the added height under wind-pressure, without the necessity of staying the guides at the top of the additional length of the standards, where obviously they would have superior leverage, regarding the standard as a lever fixed to the foundations in the The Author.

The Author. ground. The remarks of Mr. Cripps upon tank-construction were very interesting and instructive. He was in agreement with that gentleman in regard to the difference between putting the waterproof skin of the tank behind the brickwork in the one case, with puddle, and in front of the brickwork or concrete in the other case, with cement rendering. The importance of having no stretching or tightening up of the concrete wall of the tank against the ground behind it had been so long realised by the Author that he invariably filled in the trench with a perpendicular wall of concrete introduced under pressure as the timbers were withdrawn, so that any stretching such as Mr. Cripps alluded to was out of the question. More especially was this clear when the weight of any earth backing was compared with the weight of water opposed to it. He concurred with Mr. Cripps as to the extreme difficulty of erecting metal tanks of large diameter, by reason of the impossibility of connecting the sections, whether by rivets or bolts, in a manner giving adequate strength; belts to such structures always involving special mechanical difficulty in adjustment as to tightness, and in elasticity. He could hardly hope to deal with the special branch of tank- and gasholder-building at the length which Mr. Cripps had adopted in his criticism, as the Paper could not have come within the limits assigned to it. The objection to Mr. Cripps' suggestion of segmental discharging-pipes to purifiers was that the temporary joints between the sections, broken every time the purifier was discharged, would be liable to leakage and contamination of the gas. In this matter, as in the question of scrubbers, the rigour of the tests applied to the gas under the administration of the London County Council was such, as illustrated by the Table given by Mr. Walter Hunter, that few provincial gas-engineers had any idea of the delicacy of the conditions to be constantly maintained. As to the tie-bolts in the purifier-covers, he was pleased to have Mr. Cripps' concurrence. He believed that he had been the first to make an entire purifier-cover without a water-seal, and held in place in the manner shown in the diagram, Fig. 6, Plate 2. Replying to Mr. Griffith's criticism in reference to capital, he could not accept the suggestion that his figure of cost for small gasworks was misleading as being too low. Small works were necessarily simple in construction and free from complicated and expensive machines. A works having an output of 50 million cubic feet per annum was not a very small one. It was agreed, however, that the rates per million cubic feet increased rapidly as the smaller scales were

approached, so that a works of 2 or 3 million cubic feet per annum would cost £1,200 per million cubic feet. It was satisfactory to see that Mr. Humphrys concurred in the great progress due to the incandescent burner and the coin-meter. The Author had not failed to point out the necessity for the producer of gas giving assistance and advice to the consumer, and it was one of the effects of the sliding-scale legislation that attention had been drawn to this as well as to the question of low price. Especially had the furnishing of stoves and fittings by producers led to more contact between producers and consumers, and to a better knowledge of the value of gas on one side, and of the needs of those who used it on the other. He had met in many cases such autocratic regulations enforced by producers upon the consumers that he quite agreed with Mr. Humphrys' view on that point, and he had always removed such regulations where he had had the power to do so. Mr. Hunt had agreed with him as to the advance due to the Welsbach mantle and to the coin-meter, but from a municipal point of view saw no value in the sliding scale. Speaking more from the side of "Company" suppliers of gas, he had found the sliding scale most helpful in bringing about reductions in the price of gas. Mr. Hunt had referred to the London company which the Author directed as not having made much use of stoking-machinery until recent years. He overlooked the fact that until that period two out of the three works of the Commercial Gas Company had been working on too small a scale to employ machines profitably, and that it had only become profitable to do so when, owing to the alteration in the hours and the cost of labour, the balance lay with the machine as against hand labour. On that point Mr. Livesey had spoken very clearly. Mr. Hunt's remarks about inclined retorts were sufficiently met by Mr. Carpenter's observations in the discussion. As to the question of the economy of removing carbonic acid from carburetted water-gas, it was obviously a question of balance of cost between oil and lime. It might hardly be worth while to use additional oil at 3*d.* per gallon, and certainly not when it reached a price of 4½*d.* per gallon, as it had done recently. The Author was astonished to learn that water-gas had not assisted in the removal of naphthalene at Birmingham. It might be explained on the supposition that Mr. Hunt had been manufacturing water-gas of low illuminating-power, not needing enrichment to the extent necessary in London. Here again he had stated facts ruling over several years, and he could not but be surprised that similar results were not realised elsewhere.

The Author

The Author. With regard to the omission from the Paper of any reference to columnless gasholders, he could only say that the Paper was intended to deal with what he could rely upon and approve. Mr. Livesey had only, so far as the Author knew, abandoned the framing for the top lift of his gasholders, through finding the lower lifts of the existing holders of sufficient surplus strength, or, in new work, by constructing the lower part of the guide-framing of additional weight and strength. He desired to repeat that the extra leverage on the higher gasholders could best be met by carrying up the guide-standards and staying them by diagonal rods and horizontal girders at the height where such rods were most effective in restraining the movement of the standard under stress. It was simply a question of putting the strength in another part of the framing, and not of dispensing altogether with framing. Whilst Mr. Hunter's criticism was only too favourable, it was valuable, by comparing the figures of capital, and also the results of purification, between different companies, as showing that the aims of the Author, whether in capital cost or in efficiency of manufacture, had not been misdirected. The Author appreciated Mr. Hutton's remarks as showing the practice on the other side of the Atlantic, but they did not call for further comment than to notice his statement that electrolysis, which formerly had done much harm in Brooklyn, had been partially cured by the use of such return-conductors as, in the present session of Parliament, the gas- and water-companies of London had in vain sought to enforce on the tramway and railway authorities. Finally, it would be found that those who had entered into the discussion had largely answered one another. In the main points he was glad to have the concurrence of so many of those engineers who were practically dealing with the questions in important spheres of action.

23 April, 1901.

JAMES MANSERGH, President,
in the Chair.

It was resolved—That Messrs. G. E. W. Cruttwell, E. P. Hill, F. Hudleston, B. Mott, A. H. Preece, L. Robertson, J. J. Webster, and L. S. Zachariasen be appointed to act as scrutineers, in accordance with the By-laws, of the ballot for the election of the Council for the year 1901–1902.

It was announced that the Associate Members hereunder mentioned had been transferred to the class of

Members.

ROBERT ALFRED CARR. | GERALD WILLIAM PARTRIDGE.
HERBERT PETER BARROW RIGBY.

And that the following Candidates had been admitted as

Students.

CONNELL WILLIAM LONG ALEXANDER.
GEORGE HERBERT BLACKLOCK, B.A. (*Cantab.*)
ROBERT BROWNE DUNWOODY.
THOMAS REGINALD PELHAM LANE.
HERBERT FETHERSTON LLOYD.
ARCHIBALD HUGH MCMURDO.
JOHN POLLOK.
FREDERICK MICHAEL BARBANEL ROSENTHAL.
ROGER WHITLEY, B.A. (*Cantab.*)

The Candidates balloted for and duly elected were: as

An Honorary Member.

JAMES DEWAR, M.A., LL.D., F.R.S.

Members.

AMÉDÉE MARIE JOSEPH ALBY.
WESTGARTH FORSTER BROWN.
WALTER RALPH HERRING.
MONTAGUE RAFFINGTON MELLOR.
FREDERICK MILLS.
PHILIP WATTS.

Associate Members.

WILLIAM CHARLES CARTER.
HENRY MATTHIAS CLARKE.
REGINALD SORRÉ COLE, M.A. (*Cantab.*)
ANDREW MARSHALL DOWNIE, B.Sc. (*Glas.*), Stud. Inst. C.E.
FREDERICK ARTHUR HURLEY, F.C.H.
ARTHUR JOHN IRWIN, B.A.I. (*Dubl.*)
ARTHUR CLIFTON KELLY, Stud. Inst. C.E.
JOHN KIRKLAND, B.Sc. (*Victoria*).
JAMES LORD.
JAMES CHARLES O'CONNELL, B.E. (*Royal.*)
GEOFFREY HOPE PEARSON, Stud. Inst. C.E.
DAVID WILLIAM ROSS.
WILLIAM HENRY BOURCHIER SAVILE, Stud. Inst. C.E.
SYDNEY ARTHUR SMITH.
RICHARD ERNEST WRIGHT.

The discussion upon the Paper by Mr. Harry E. Jones, on "Modern Practice in the Manufacture and Distribution of Gas," occupied the evening.

ANNUAL GENERAL MEETING.

30 April, 1901.
JAMES MANSERGH, President,
in the Chair.

The Notice convening the Meeting was taken as read, as well as the Minutes of the Annual General Meeting of the 24th April, 1900, which the President was authorized to sign.

The Report of the Council upon the Proceedings of the Institution during the Session 1900–1901 was read, the Statement of Accounts being taken as read.

After consideration, it was resolved,—That the Report of the Council be received and approved, and that it be printed in the Minutes of Proceedings.

The Scrutineers reported the election of the Council for 1901–1902 as follows :— [1]

President.

CHARLES HAWKSLEY.

Vice-Presidents.

Sir William Henry White, K.C.B., D.Sc., LL.D., F.R.S.
John Clarke Hawkshaw, M.A.
Francis William Webb.
Sir Guilford Lindsey Molesworth, K.C.I.E.

Other Members of Council.

James Barton, B.A.
Horace Bell.
Sir Alexander Richardson Binnie.
Benjamin Hall Blyth, M.A.
Cuthbert Arthur Brereton.
Thomas Forster Brown.
Robert Elliott Cooper.
Cecil West Darley.
George Frederick Deacon.
William Robert Galbraith.
Edmund Phillips Hannaford.
George Henry Hill.
James Charles Inglis.
Alexander Blackie William Kennedy, LL.D., F.R.S.
Anthony George Lyster.
John Allen McDonald.
Edward Pritchard Martin.
William Matthews, C.M.G.
William Shelford, C.M.G.
Alexander Siemens.
Thomas Stewart.
John Strain.
John Isaac Thornycroft, F.R.S.
William Cawthorne Unwin, B.Sc., F.R.S.
Frederick Robert Upcott, C.S.I
Sir Edward Leader Williams.

[1] The Council commence their year of office on the first Tuesday in November, 1901.

Resolved,—That the thanks of the Meeting be given to the Scrutineers, and that the Ballot-Papers be destroyed.

Mr. John J. Webster responded on behalf of the Scrutineers.

Resolved,—That the thanks of the Institution be tendered to Messrs. John George Griffiths and Alexander Ross, for the time and trouble bestowed by them in auditing the Accounts for the past financial year; and that they be re-appointed Auditors for the ensuing year.

Messrs. Griffiths and Ross acknowledged the Resolution.

Resolved,—That the thanks of this Meeting be accorded to Mr. James Mansergh, President, for his conduct of the business as Chairman of the Meeting.

The President acknowledged the Resolution.

The proceedings then ended.

REPORT OF THE COUNCIL, 1900-1901.

BEFORE presenting, in accordance with the By-laws, the yearly report upon the state of the Institution, the Council have to record here the deep sense of the loss felt by the members in every part of the world on the death of Her Majesty, Queen Victoria, whose beneficent reign witnessed the progress of the Institution since the period when the chair was occupied by James Walker, its second President.

The members will learn with great satisfaction that His Majesty the King has been pleased to signify his intention to honour the Institution by becoming its Patron, thus continuing in a more marked degree the countenance and support afforded by his connection with it since he became an Honorary Member in 1865.

During the past Session considerable effort has been made to promote efficiency in the discussion of the Papers presented at the weekly meetings. It has long been recognised as impracticable to advise each member individually of every Paper about to be submitted for discussion, even were that course likely to be of advantage. Such notification has however been made to those who were understood to have special experience in the various subjects under consideration. An attempt has now been made to extend this notice, and to arrange for the issue of early (unedited) proofs of the Papers, if requested, to a much larger number of members—broadly classified as to special practice—so far as the subjects appear to touch their particular branches of work.

To give effect to this departure—still in an initial and necessarily incomplete state—some 20,000 personal notices were issued during the session. The practice seems to have been justified by an enhanced interest taken by many members in the discussions, both orally and in writing, to which reference will be made later.

Another matter which has engaged the close attention of the Council is the better definition of the requirements for Corporate Membership. The last Annual Report contained an explanation of the *regular education* contemplated by the By-laws as a condition

of election into the Institution. As regards the scientific training of candidates, the Council have resolved that, the examinations (having now been in operation for 4 years) must be submitted to by every candidate who was under 30 years of age on the 1st January, 1901—and that substitution of the test by Thesis should only be allowed in other cases after special inquiry into the circumstances by the examinations Committee.

It must be reiterated that the scientific qualifications thus insisted on are not in any sense a substitute for the practical qualifications demanded of Candidates for Election. And especially should Students of the Institution, and others who may contemplate adopting the career of instructors in engineering and technical colleges, bear in mind that the recognition of professional status conferred by the Institution diploma can only be accorded to persons qualified by a proper course of practical engineering experience.

Attention has on many occasions been drawn to the admission into the Institution of persons who are not British subjects. The Council, after duly considering the matter, have arrived at the conclusion that the admission of such persons to full Membership should be restricted to those who are of exceptional and acknowledged eminence in the profession; and that, with regard to Associate Membership, the Institution examination should in all such cases be insisted on.

Whilst endeavouring in these and in other directions to promote the efficiency of the Institution, the Council have not refrained from asserting its position, when they considered it to be in the interests of the members and of the profession generally to do so. Thus, in the course of the session it became necessary to oppose an application made by the Institution of Mining and Metallurgy for the grant of a Royal Charter of Incorporation. Concurring in the views held by their predecessors on several occasions of a like kind, the Council submitted that it was adverse to the interests of engineering science, that the recognition formally accorded to the Institution of Civil Engineers by Royal Charter in 1828, as representative of all the departments of mechanical science, should be extended to societies dealing with branches of engineering, whose members might, if properly trained and qualified, enter this Institution.

The statement and reasons put forward against the application in question are appended for the fuller information of the members:—

STATEMENT AND REASONS AGAINST THE PETITION FOR A CHARTER OF INCORPORATION TO THE INSTITUTION OF MINING AND METALLURGY.

The Institution of Civil Engineers was established in the year 1818, and was incorporated by Royal Charter in 1828, "For the General Advancement of Mechanical Science."

Members of every branch of Engineering, except Military Engineering, are, if properly trained and qualified, eligible to enter the Institution, and its influence is shown by the fact that on the 1st January last it consisted of:—

Honorary Members	17
Members	2,029
Associate Members	4,007
Associates	300
Students	974
Making a total of . .	7,327

This influence has been recognised to be of public advantage by subsequent Royal Charters, which were granted to the Institution in 1887 and 1896, enlarging the scope of its work and responsibilities, and by the recent appointment by the Crown of Sir John Wolfe Barry, K.C.B., representing the Institution, upon the Senate of the London University.

In addition to its periodical meetings and discussions, its lectures and its publications (now amounting to 142 volumes), the Institution tests by examination the general education and special scientific attainments and investigates the personal qualifications of those who seek admission to its ranks. The result of this scrutiny and care and of the supervision exercised by the Council has been that in every quarter of the world membership of the Institution of Civil Engineers is accepted as a guarantee of professional competence and of integrity.

Where every branch of civilian Engineering is included, it need hardly be stated specially that Engineers engaged in mining and metallurgical operations are strongly represented. This branch of the profession is represented on the Council of the Institution; and as an illustration of the position occupied by it in the various mining districts of the world, it may be mentioned that in South Africa alone there were lately no fewer than 239 members of this Institution, the large majority of whom were concerned with Mining Engineering.

There are in the United Kingdom Engineering societies of high reputation and established position, whose members are particularly concerned with some special branch of Civil Engineering. These societies, such as the Institution of Mechanical Engineers, the Institution of Electrical Engineers and others, consist to a considerable extent of members of the Institution of Civil Engineers, who thus secure the status of attachment to a central Institution representing the Engineering profession generally, and also the benefit of belonging to bodies more particularly concerned with the branches of work in which they are respectively interested; but in order that the central Institution may retain the influence which has enabled it to promote the attainment of the present position occupied by Engineers, it is submitted that the distinction of incorporation by Royal Charter should continue to attach to it alone so far as the Engineering profession is concerned.

For this reason the Council of the Institution of Civil Engineers beg leave to protest—as they have done under similar circumstances on several previous occasions—that it would not be to the public advantage that a Royal Charter of

Incorporation should be granted to a body proposing to represent a particular branch of Civil Engineering already covered by the work of the Institution of Civil Engineers: and they would urge that no cause is shown in the Petition presented by Charles Algernon Moreing and others, why the Institution of Mining and Metallurgy should receive such a privilege.[1]

5 February, 1901.

The numbers attending the Institution examinations have been well maintained; and it is satisfactory to record 118 passes secured during the session in the Associate Membership examination; whilst it may be observed that, of those who have applied for election in the same period, forty-six were exempt from examination through the possession of recognised degrees or diplomas.

The experience of the working of the examination system during the past four years has naturally shown from time to time where modifications in the rules and syllabus might be advantageously made, especially in the direction of diminishing the practical difficulties experienced by Candidates who have to attend the examinations whilst engaged in active engineering work. The rules thus revised and consolidated have recently been adopted by the Council, and should be consulted carefully by intending Candidates.

The Roll.

The accompanying Table shows the changes that have taken place in the Roll during the year ending the 31st March,

	April 1, 1899, to March 31, 1900.					April 1, 1900, to March 31, 1901.				
	Honorary Members.	Members.	Associate Members.	Associates.	Totals.	Honorary Members.	Members.	Associate Members.	Associates.	Totals.
Numbers at commencement	20	2,004	3,953	326	6,303	19	2,033	3,989	311	6,352
Transferred to Members	..	79	79	..		..	73	73	..	
Elections	..	26	192	5	232	3	25	166	5	206
Restored to Register	..	2	6	1		..	2	5	..	
Deaths	1	55	33	14	183	2	47	40	7	182
Resignations	..	14	20	2		1	12	25	9	
Erased	..	9	30	5	49	..	7	32	..	24
Numbers at termination	19	2,033	3,989	311	6,352	19	2,067	3,990	300	6,376

[1] It was subsequently announced that the Privy Council had not seen fit to advise the grant of a Royal Charter to the Institution of Mining and Metallurgy. —See Inst. C.E.

1901. The elections were 3 Honorary Members, 25 Members, 166 Associate Members and 5 Associates; and the names of 2 Members and 5 Associate Members were restored to the register —making a total addition of 206. Owing to death, resignation and erasure, 182 names disappeared from the list. The number on the Roll, exclusive of Students, on the 31st March, 1901, was 6,376, as against 6,352 on the corresponding date of last year.

Among the deceases recorded are those of H.R.H. the Duke of Saxe-Coburg-Gotha and Dr. William Pole, Honorary Members, and a distinguished Past-President, Lord Armstrong.

Among resignations of Associates appear the names of Lord Alverstone and Sir William Chandler Roberts-Austen, who resigned upon their nomination for election as Honorary Members, and that of Professor Kernot, who has since been elected a Member.

The full list of deceases is as follows:—

Honorary Members.—H.R.H. Alfred, Duke of Saxe-Coburg-Gotha, K.G.; and Dr. William Pole, F.R.S.

Members.—Lord Armstrong, C.B., LL.D. (*Cantab.*), D.C.L. (*Oxon and Durham*), M.A.I. (*Dubl.*), F.R.S., *Past-President*; Professor George Frederick Armstrong, M.A. (*Cantab.*); Henry Bancroft; Charles Edwin Brown; William Duff Bruce; George Brunton; Alfred Davidson; George Workman Dickson, B.A. (*Dubl.*); Charles de Neuville Forman; James Richardson Forman; George Baker Forster, M.A. (*Cantab.*); William Gill; John Viret Gooch; George Clementson Greenwell; Richard Hack; Henry Edmunds Haddon; Harry Pasley Higginson; Robert Jacomb-Hood; Henry Law; Alexander Luders Light; William Lindley; Thomas David Little, C.I.E.; Francis Blayney Maclaran; Francis William Martin; Andrew Morton; Edmund Olander; Augustus Tichborne Pentland, M.A. (*Dubl.*); Edward Pritchard; Richard Proctor-Sims; Professor Callcott Reilly; Robert Andrew Robertson; Richard Barnsley Sanders, B.E. (*Royal*); Charles Sells; Hamilton Smith; James William Smith; Henry Francis Sneyd-Kynnersley; William Kitson Stent; Charles Stone; John Strapp; Charles Tylden-Wright; Philip Billingsley Walker; Rienzi Giesman Walton; Lawrence Fletcher White; James Wilson (1888); William John Wilson, F.C.H.; Robert Wingate; and Matthew Woodifield.

Associate Members.—Eliseo Anzorena; Arthur Barclay; John Hopwood Blake; Edward Henry Bold; Arthur Kaye Brown; Thomas Edward Candler; James Husband Carvosso; Thomas Burnside Crowther; Frederick Davis; Mark Edward Drury; Herbert Henry Grahame Dunlop; Arthur Montefiore Wire Easten; Robert Thomas Greer, B.E., LL.B. (*Royal*); Charles Edward Grove; Charles Hall; Gerald Maitland Heriot; John Cartmel Holme; Charles Frederick Hughes-Hallett, M.A. (*Cantab.*); Richard Carruthers Ivy; Walter Jenkins; William Henry Coryton Kempe; James Lovegrove; William MacLeod Mackinnon; Henry Cripps Matheson; Hugh McPherson Mitchell; Thomas Nuttall; Robert Stewart Oliver; Thomas Ellis Owen; Manuel Hipolito Peña; Charles George Washington Phillips; John Porter; William Sancroft Randall; William Warren Smith; Frederick William Stevens, C.I.E.; Alexander

Stewart; Hubert Townsend Storrs, B.Sc. (*Victoria*); James Donnithorne Thomas; John Thompson; William Stephen Watson; and Thomas Edward West.

Associates.—John Bayliss; Charles Barry; Henry Currey; Charles Henry Driver; Sir Thomas McIlwraith, K.C.M.G., LL.D. (*Glas.*); Joseph Bond Morgan; and the Hon. Foley Charles Prendergast Vereker, *Captain* R.N.

The following resignations have been accepted:—

Members.—Charles Albert Bull; Robert Edwards; John William Hart; Stephen Horsley; William Stuart Howard; Charles Malcolm Johnson, R.N.; Walter Katte; Andrew Oliver Lyons; George Walter MacGeorge; Henry Sadleir Ridings, M.E. (*Queen's*); James Strachan, C.I.E.; and Charles James Knight Watson.

Associate Members.—Leonard Hodgson Appleby; Reginald Brooks-King; James Samuel Butler; Archibald Ross Colquhoun; Henry Streatfeild Cotton; William Crickmay; Edmond Power Dowley, B.A., B.E. (*Dubl.*); William Leigh Hamilton; Thomas Charles John Harrison; William Prest Housden; George Edward Jenkins; William Hubert Kinch; Herbert John Landon; Thomas May (1879); Edward Monson; Kenneth McLaurin Monteath; Arthur Daniel Moullin; Charles Prouse; John Christopher Rolleston; John Ross; Ernest Edward Scholefield; Frederick Henry Smith; Arthur Southam; Samuel Nathaniel Squire; and Benjamin Kelly Thorpe.

Associates.—Lord Alverstone, G.C.M.G., LL.D. (*Cantab.*); George Alfred Barnett, C.I.E.; Frederick Firebrace, *Colonel* R.E. *retired*; Henry Griffiths; Professor William Charles Kernot; Henry Dacres Olivier, *Lieutenant-Colonel* R.E.; Robert Charles Boileau Pemberton, *Major-General* R.E. *retired*; Sir William Chandler Roberts-Austen, K.C.B., F.R.S.; and Arthur Sinclair.

Admission of Students.

The changes which have taken place in the Student class during the year ending the 31st March, 1901, are shown in the accompanying Table. The admissions numbered 185, while 221 names

Students.

1899–1900.			1900–1901.		
April 1, 1899		964	April 1, 1900		1007
Admitted during the year	263		Admitted during the year	185	
Elected Associate Members	36		Elected Associate Members	41	
Resigned	18		Deceased	2	
Erased	8		Resigned	27	
Removed—over age	158		Erased	22	
	220		Removed—over age	129	
	43			221	
				36	
March 31, 1900		1,007	March 31, 1901		971

were removed from the list. Of these 41 were elected to the Associate Member class, and 129 had attained the age-limit of the

Student class. Of the 166 candidates elected to the Associate Member class during the twelve months under review, exactly one-half were, or had been formerly, Students. On the 31st March the total number of Students was 971. A large majority of the candidates for admission now hold degrees or certificates which are recognised by the Council as affording evidence of satisfactory general education; but a considerable number continue to avail themselves of the Institution Examination in order to obtain qualification. The number thus passed during the Session was 63.

Finance.

The Statement of Accounts for the Financial year ending the 31st March, 1901, duly audited, will be found at p. 136.

The receipts on Income account amounted to £23,036 3*s.* 2*d.*, which compares with £22,735 1*s.* 8*d.* last year; on Capital account (admission fees and life compositions) £2,155 13*s.*; and from Trust Funds £464 3*s.* 7*d.*: making a total of £25,655 19*s.* 9*d.* The several items received on Income account were: subscriptions £19,168 3*s.*, dividends £1,759 18*s.* 9*d.*, rents £985 4*s.*, examination fees £430 10*s.*; and repayment of binding charge and miscellaneous items, £692 7*s.* 5*d.*

The expenditure on Income account amounted to £21,459 15*s.* 11*d.*, against £21,465 17*s.* 2*d.* last year; and the sum chargeable to Trust Funds was £357 7*s.* 8*d.*, while on Capital account the sum of £8,085 2*s.* was invested in Manchester Corporation 3 per cent. Stock and London County 3 per cent. Consolidated Stock.

The investments on Institution account now amount to £61,600 (nominal value), purchased for £62,969 7*s.* 8*d.*, and the funds held in trust to £17,144 0*s.* 9*d.* (par value).

Sessions and Meetings.

During the Session twenty ordinary meetings only were held, those announced for the 22nd and 29th January having been abandoned in consequence of the death of the Sovereign. The first meeting was occupied by the President's inaugural address. At the remaining meetings fourteen Papers were read, namely—"The Metropolitan Terminus of the Great Central Railway," by Messrs. G. A. Hobson and E. Wragge; "Machinery for the Manufacture of Smokeless Powder," by Mr. O. Guttmann; "The Signalling on the Waterloo and City Railway," and a "Note on the Signalling of Outlying Siding-Connections," by Mr. A. W.

Szlumper; "Signalling on the Liverpool Overhead Railway," by Mr. S. B. Cottrell; "Glasgow Bridge," by Mr. B. H. Blyth; "Railway Bridge over the Fitzroy River at Rockhampton, Queensland," by Mr. W. J. Doak; "The Niagara Falls and Clifton Steel-Arch Bridge," by Mr. L. L. Buck; "The Present Condition and Prospects of the Panama Canal Works," by Mr. J. T. Ford; "The Nilgiri Mountain Railway," by Mr. W. J. Weightman; "The Rotatory Process of Cement Manufacture," by Messrs. W. H. Stanger and B. Blount; "The Æsthetic Treatment of Bridge Structures," by Mr. J. Husband; "The Burrator Works for the Water Supply of Plymouth," by Mr. E. Sandeman; and "Modern Practice in the Manufacture and Distribution of Gas," by Mr. H. E. Jones.

Whilst all these Papers were selected as raising questions of importance in the various branches of Engineering touched by them, special interest attached to several of the subjects upon wider grounds than those afforded by features of construction alone. Noticeably, Mr. Ford's communication on the Panama Canal contained a forcible plea for not abandoning the work already done on one of the most feasible routes across the Isthmus. The Paper on the new rotatory system of making Portland cement evoked considerable interest, as forecasting a revolution in the production of a material of construction most extensively used by the engineer. Mr. Husband's Paper on the æsthetic design of bridges broke new ground as regards this Institution, and elicited a well-sustained and useful discussion. On the discussion upon the Burrator Reservoir, an important question was raised in relation to the increase and wider diffusion of knowledge concerning the proportion of rainfall rendered available by the construction of reservoirs of definite capacity on particular streams.

It is satisfactory to observe that, probably owing partly to the measures referred to earlier in the Report, the Papers have been discussed more fully than in recent years. The number of those who took part in the discussions orally and in writing has averaged 14 per Paper—a figure which compares favourably with the proceedings of other scientific societies, being more than double that attained on the average by six other principal engineering societies in England and the United States.

For the Papers read at the Meetings, the Council have had pleasure in making awards to Messrs. H. E. Jones, G. A. Hobson and E. Wragge, J. Husband, J. T. Ford, L. L. Buck, W. H. Stanger and B. Blount, W. J. Doak, and E. Sandeman.

The communications selected for publication in the Minutes of Proceedings without being read have ranged over a very wide field, and are too numerous for individual mention in this Report. The task of appraising their merit, as a preliminary to the premiation of the best of them, will engage the Council's attention during the recess, and the awards will be intimated in the autumn. The formal presentation of medals and premiums will take place as usual at the first meeting of the ensuing session.

Students' Meetings and Visits to Works.

Nine Students' meetings were arranged for, but one of these was abandoned in consequence of the Queen's death. At that held on the 11th January, Mr. Wilfrid Airy, B.A., M. Inst. C.E., delivered a valuable address on "Geodesy," a copy of which has since been supplied to every student on the list. At the remaining meetings Papers have been read and fairly discussed, and eight ordinary visits have been made to Engineering works; but neither in respect of the meetings nor of the visits has the interest exhibited by the Students been quite what might be expected, having regard to the number residing in or near London.

The following Table shows the average attendance at meetings and visits to works for the past three Sessions:—

Table of Average Attendance.

Session.	1898–1899	1899–1900	1900–1901
At meetings	42·1	40·5	36
„ visits	19·6	25	20·5

Twelve Students' Papers have been read before meetings of the local associations, ten of which have been entered in competition for the Miller Prizes.

A special series of Students' visits in and near London has been arranged, by the kindness of several Members, for the 2nd and 3rd May, on the latter of which days the Students' Twenty-sixth Annual Dinner is to be held.

The "James Forrest" Lecture.

The ninth "James Forrest" lecture was delivered on the 25th April by Professor Frank Clowes, D.Sc., whose treatment of the subject "Chemistry in its relations to engineering" formed a valuable addition to the series of addresses inaugurated by that
iam Anderson in 1893.

Library Catalogue.

The compilation of the Subject Catalogue of the Library, entrusted by the Council to Mr. Henry B. Wheatley, is reported as complete in MS., and is being set in type as rapidly as possible. A considerable portion is already available for reference in the library, and it is hoped that the unavoidable delays incident to the earlier stages of the work will be recovered as far as possible by a speedy issue of the remainder.

The Premises.

The Institution premises have been kept under careful observation during the excavating and building operations on the adjacent land; and precautions have been taken by the Board of Works to prevent as far as possible the risk of damage to the structure from the works now in progress.

It was decided a year ago to protect the portraits in the theatre by glazing, and this work was carried out in the summer recess. The Council are glad to record the addition to the collection of the portrait of Sir Douglas Fox, Past-President.

General.

It may be appropriate to notice, in conclusion, several events which, although not forming directly part of the ordinary work of the Institution, exercise an influence on its relations with other important societies, and consequently on the sphere of its usefulness.

First may be mentioned the reception last June by the *Société des Ingénieurs Civils de France*, of representatives of technical and learned societies, on the occasion of the Paris Exhibition. In the unavoidable absence of the President, Mr. Horace Bell, Member of Council, and the Secretary attended the various official receptions, where a most cordial welcome was extended to them as delegates of the Institution—Mr. Bell being in that capacity called upon to occupy the position of principal guest at the banquet with which those functions concluded.

The Council refer with pleasure to the interesting occasion in July, when a party of 222 members of American engineering societies was received here. The special honour accorded to the Institution and its visitors by Queen Victoria, in receiving them at Windsor Castle on the 3rd July, will be long remembered. By the courtesy of the Lord Mayor and the Corporation of the City of London, the Institution, under the Presidency of Sir

Douglas Fox, was enabled to entertain its American guests on the 5th July at the Guildhall; and on the following day the visit paid to Warwick Castle and to Stratford-on-Avon was rendered memorable by the kindness and attention shown to the party by the Earl and Countess of Warwick.

That our American visitors appreciated the efforts made to give them a hearty welcome, it is unnecessary to say; but the members of the Institution may be gratified to read the warm terms in which the American Societies of Civil and Mechanical Engineers have expressed that appreciation in their official addresses since received here, copies of which are appended:—

To the President, Past-Presidents, Vice-Presidents, Council and Members of The Institution of Civil Engineers.

THE Board of Direction of the AMERICAN SOCIETY OF CIVIL ENGINEERS, acting in behalf of the Society as a body, and of its individual members, hereby tenders hearty thanks for the many courtesies received in connection with the Thirty-second Annual Convention of the Society.

Your cordial invitation to visit London, in a more or less organized body, during 1900, was accepted in the belief that a material and lasting benefit would be derived from the holding of a meeting of Engineers which would be international in character.

The meeting of this Society, held in the home of the parent Engineering Association of the World, brought together, for the exchange of professional views, a large number of Engineers, comprising representatives from nine widely separated nations, and it is believed that the interest manifested, and the resulting technical discussions, fully justified the inauguration of such International Meetings.

Apart from the professional feature, the graceful and magnificent entertainments and excursions, arranged in behalf of American Engineers, are highly appreciated by our members, individually and collectively; the more so from a realising sense that such a reception could have been carried out only by an Institution whose standing and position before the public are established beyond question.

While, therefore, our thanks are due primarily to the Institution, we desire to record our profound appreciation of the high honour conferred upon the profession in America by Her Gracious Majesty Queen Victoria in receiving its representatives at her Castle at Windsor. We also wish to acknowledge the charming hospitality of the Earl and Countess of Warwick, and the kindness of the Lord Mayor, Aldermen and Common Council of the City of London in tendering their ancient Guildhall for the occasion.

We finally desire to express the hope that a similar meeting may be held in America at no distant day, and that the Engineers of Great Britain may derive therefrom some measure at least of the profit and pleasure which in this instance has accrued to their American Brethren.

SEAL OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

(Signed) JOHN F. WALLACE, *President.*

(Signed) CHAS. WARREN HUNT, *Secretary.*

To the President, Council and Members of
The Institution of Civil Engineers.

Greeting:

We, the President, Council and Members of

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS,

In full recognition of the hospitality extended to us by your Institution during the past summer, hereby extend this official acknowledgment.

Realising the profound International significance, at this time, of certain of the events included in the reception by the Institution of Civil Engineers of their American professional brethren,

And fully appreciating the remarkable social courtesies so gracefully extended, we here record the sincerest thanks of the American Society of Mechanical Engineers.

In all those graceful courtesies, the ever-growing ties between the Members of the Anglo-Saxon Race throughout the World are evidenced and strengthened.

We take this as a welcome opportunity to record our deep appreciation and hearty thanks.

FOR THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS—

SEAL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

CHAS. H. MORGAN, *President.*

F. R. HUTTON, *Secretary.*

Notice has been already widely given of the arrangements made for holding an International Engineering Congress at Glasgow in September.

The President of the Institution has accepted the invitation to be President of the Congress; Sir Douglas Fox, Past-President, is Chairman of the London Committee, under whose advice the general scheme of administration was arranged; Sir Benjamin Baker and Sir John Wolfe Barry, Past-Presidents, have lent their aid as chairmen of the sections dealing with railways, and with waterways and maritime works, respectively; whilst many other Members have agreed to take an active part in the proceedings. The Institution has thus shown its interest in the undertaking, and the Council believe that a successful Congress may be confidently expected.

The Council intimated some weeks ago that owing to the national mourning for the late Queen they did not propose to make arrangements for the customary Annual Dinner this year, and do not doubt that the members have concurred in the propriety of that decision. They hope the Conversazione, to be held at the Institution on the 19th and 20th June, will be as well attended and as successful as those of former years.

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS.

Dr.	£. s. d.	£. s. d.
To Balance, 1 April, 1900, viz. :—		
On Deposit	6,000 0 0	
Cash in the hands of the Treasurer	4,718 7 10	
„ „ „ Secretary	2 15 7	
		10,721 3 5
Income.		
— Subscriptions received :— £. s. d.		
Arrears, prior to 1 January, 1900 : 390 12 0		
For the year 1900 4,760 9 0		
For the year 1901 14,011 17 0		
Advance 5 5 0		
	19,168 3 0	
— Minutes of Proceedings :—Re-payment for Binding, &c.	514 15 0	
— Library Fund	88 8 6	
— Dividends : 1 year on		
Institution Dividends.		
£		
2,000 2¾% Consols . . .	52 9 7	
6,000 Metropolitan 3½% Stock	200 7 6	
6,000 Great Eastern Railway 4% Debenture Stock.	229 0 0	
8,000 Great Northern Ry. 3% Debenture Stock . .	229 0 0	
8,000 Great Western Ry. 4% Debenture Stock . .	305 6 8	
8,000 Lancs. & Yorks. Ry. 3% Debenture Stock . .	229 0 0	
6,000 London & N.W. Ry. 3% Debenture Stock . .	171 15 0	
9,600 Midland Ry. 2½% Debenture Stock . .	229 0 0	
New Purchases.		
4,000 Manchester Corporation 3% Stock	114 0 0	
4,000 London County 3% Stock	0 0 0	
	1,759 18 9	
£61,600 Nominal or par value.		
— Rents—No. 27 Great George St.	985 4 0	
— Examination Fees	430 10 0	
— Interest on Deposit	94 3 11	
		23,036 3 2
Carried forward		£33,757 6 7

from the 1ST APRIL, 1900, *to the* 30TH MARCH, 1901.

EXPENDITURE.

Cr. GENERAL EXPENDITURE.

	£. s. d.	£. s. d.	£. s. d.
By House and Establishment Charges:—			
Repairs:— General		53 1 7	
Rent of No. 27 Great George Street		600 0 0	
Rates and Taxes:—The Institution	980 16 8		
No. 27 Gt. George St.	181 8 4		
		1,162 5 0	
Insurance:—The Institution	84 8 0		
No. 27 Gt. George St.	3 8 0		
		87 16 0	
Fixtures and Furniture, Glazing Pictures		172 1 1	
Lighting, Warming and Ventilating:—			
The Institution	290 13 10		
No. 27 Gt. George St.	11 5 9		
		301 19 7	
Charges for Water (including lifts), Rent of Telephone, &c.	100 17 0		
Charges for Water, No. 27 Gt. George St.	18 6 0		
		119 3 0	
Refreshments at Meetings		95 8 5	
Assistance at Meetings		29 17 0	
Students' Meetings (including refreshments), Donation to Annual Dinner, and Visits		228 19 10	
Household Expenses		441 10 10	
			3,292 2 4
— Postages, Telegrams, and Parcels		442 8 3	
— Stationery and Printing		967 2 2	
— Watt Medals		2 7 6	
— Stephenson Medals		4 15 0	
— Joule Medal (Inscription)		13 6	
— Diplomas		24 11 3	
— Annual Dinner (balance 1900)		264 0 0	
— Reception at Guildhall		1,401 1 4	
			3,106 19 0
— Salaries		2,675 0 0	
— Clerks, Messengers, and Housekeeper		1,538 6 4	
— Retiring Allowances and Donations		1,269 0 0	
			5,482 6 4
— Library:—Books and Periodicals		288 14 7	
Binding		251 9 3	
			540 3 10
— Publications:—			
"Minutes of Proceedings," Vols. cxl., cxli., cxlii. and cxliii.		7,864 18 9	
Charters, By-Laws, and Lists of Members		344 6 1	
			8,209 4 10
Carried forward			£20,630 16 4

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

Dr. RECEIPTS—*continued.*

	£.	s.	d.
Brought forward	33,757	6	7

CAPITAL.

	£.	s.	d.	
To Admission-Fees	2,050	13	0	
— Life-Compositions	105	0	0	
				2,155 13 0

Carried forward . .	£35,912 19 7

from the 1ST APRIL, 1900, *to the* 30TH MARCH, 1901.

EXPENDITURE—*continued.*

Cr.			£.	s.	d.
		Brought forward	20,630	16	4
By Professional Auditor's Fee	105 0 0				
— Legal Expenses (General)	27 18 6				
— Expenses of Delegates to Society of Civil Engineers, France	44 18 3				
— Expenses of Delegate to Paris Navigation Congress	26 13 0				
— Committee on Tabulating Results of Steam-Engine and Boiler Trials	51 11 6				
— Examinations	562 8 4				
— Donation to Westminster Hospital	10 10 0				
			828	19	7
			21,459	15	11

CAPITAL.

			£	s.	d.			
— Purchase of	£4,000	Manchester Corporation 3% Stock	4,085	1	0			
— Ditto	£4,000	London County 3% Consolidated Stock	4,000	1	0			
	8,000	Total nominal or par value.				8,085	2	0

Carried forward . . £29,544 17 11

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

Dr.

RECEIPTS—*continued.*

	£.	s.	d.
Brought forward	35,912	19	7

Trust Funds.

Telford Fund.

To Dividends:—1 year on

£.	s.	d.		£.	s.	d.	£.	s.	d.
5,489	11	0	2¾% Consols	142	14	10			
3,299	2	0	Ditto (Unexpended Dividends) . . .	86	11	8			
£8,788	18	0					229	6	1

Manby Donation.

£250	0	0	Great Eastern Ry. 4% Irredeemable Guaranteed Stock				9	10	10

Miller Fund.

3,125	0	0	2¾% Consols.	81	19	10			
2,004	17	5	Ditto (Unexpended Dividends). . . .	52	12	3			
£5,129	17	5					134	12	1

Howard Bequest.

£551	14	6	2¾% Consols				14	9	7

Trevithick Memorial.

£103	0	0	2¾% Consols				2	13	11

Crampton Bequest.

£512	15	11	2¾% Consols.				13	9	2

James Forrest Lecture and Medal Fund.

372	0	0	South-Eastern Ry. 5% Debenture Stock . . .				17	14	11

Palmer Scholarship.

1,381	1	6	Metropolitan 3% Stock .	39	7	4			
104	18	5	Ditto (Unexpended Dividends) . . .	2	19	8			
£1,485	19	11					42	7	0
									464 3 7
									£36,377 3 2

from the 1ST APRIL, 1900, *to the* 30TH MARCH, 1901.

EXPENDITURE—*continued.*

Cr.	£.	s.	d.	£.	s.	d.	£.	s.	d.
Brought forward							29,544	17	11
TRUST FUNDS.									
By Telford Premiums	189	9	8						
— Telford Medals	12	0	0						
				201	9	8			
— Miller Prizes				93	15	10			
— Crampton Prize				12	0	0			
— "James Forrest" Lecture (eighth)	15	4	7						
James Forrest Medal	2	15	0						
				17	19	7			
— Palmer Scholarship—									
9 months' dividend to Scholar				32	2	7			
							357	7	8
							29,902	5	7
— Balance, 30 March, 1901, viz.:—									
On Deposit				5,500	0	0			
Cash in the hands of the Treasurer . . .				957	12	11			
„ „ Secretary . . .				17	4	8			
							6,474	17	7
							£36,377	3	2

J. H. T. TUDSBERY, *Secretary.*

17 *April*, 1901.

Examined with the Books and Securities and found correct.

(Signed) JOHN G. GRIFFITHS, F.C.A.
A. ROSS. } *Auditors.*

STATEMENT OF INVESTMENTS HELD 30 MARCH, 1901.

Institution Investments.

£		£. s. d.	£. s. d.
2,000	2½% Consols	Cost 1,967 19 1	
4,000	Manchester Corporation 3% Stock .	„ 4,085 1 0	
6,000	Metropolitan 3½% Stock . . .	„ 6,517 15 0	
6,000	Great Eastern Railway 4% Debenture Stock	„ 7,749 18 3	
8,000	Great Northern Railway 3% Debenture Stock	„ 7,642 16 4	
8,000	Great Western Railway 4% Debenture Stock	„ 10,547 5 0	
8,000	Lancashire and Yorkshire Railway 3% Debenture Stock	„ 7,452 14 8	
4,000	London County 3% Stock . . .	„ 4,000 1 0	
6,000	London and North Western Railway 3% Debenture Stock . .	„ 5,544 18 5	
9,600	Midland Railway 2½% Debenture Stock	„ 7,460 18 11	
61,600			62,969 7 8

Freehold of Institution Premises and New Building:—
Cost, including buildings now removed . .. 124,379 10 0

Note.—No value has been attached, for the purpose of this statement, to the Books, Furniture, Fittings, Pictures, &c., in the Institution Building nor to the lease of No. 27 Great George Street.

Trust Funds Investments.

£. s. d.			£. s. d.
		Telford Fund.	
1,945 19 0	2½% Consols	—Acquired with a bequest of . .	2,000 0 0
3,479 12 9	do.	Converted from Government Stocks bequeathed	Bequest.
13 19 3	do.	Purchased with bonus on conversion cost	13 11 3
5,439 11 0			
3,299 2 0	do.	Purchased with unexpended dividends	3,034 18 1
8,738 13 0			
		Manby Donation.	
250 0 0	Great Eastern Railway 4% Irredeemable Guaranteed Stock		Donation.
		Miller Fund.	
3,125 0 0	2½% Consols	—Acquired with a bequest of . .	3,000 0 0
2,004 17 5	do.	Purchased with unexpended dividends	1,850 2 4
5,129 17 5			

TRUST FUNDS INVESTMENTS—*continued.*

£.	s.	d.		£.	s.	d.
			Howard Bequest.			
551	14	6	2½% Consols—Acquired with a bequest of . .	500	0	0
			Trevithick Memorial.			
103	0	0	2½% Consols—Acquired with a presentation of .	100	0	9
			Crampton Bequest.			
512	15	11	2½% Consols—Acquired with a bequest of . .	500	0	0
			James Forrest Lecture and Medal Fund.			
320	0	0	South Eastern Railway 5% Debenture Stock acquired with a subscription of	510	0	0
52	0	0	Ditto acquired with a subscription of £93 14*s.* 8*d.* and 19*s.* 4*d.* cash	94	14	0
372	0	0				
			Palmer Scholarship.			
1,381	1	6	Metropolitan 3% Stock bequeathed	Bequest.		
104	18	5	Ditto purchased with unexpended dividends . .	122	6	3
1,485	19	11				

MEDALS AND PREMIUMS AWARDED FOR THE SESSION 1899–1900, PRESENTED ON THE 6TH NOVEMBER, 1900.

FOR PAPERS READ AND DISCUSSED AT THE ORDINARY MEETINGS.

1. A George Stephenson Medal and a Telford Premium to Sir Isaac Lowthian Bell,[1] Bart., LL.D., F.R.S., M. Inst. C.E., for his Paper on "The Development of the Manufacture and Use of Rails in Great Britain."
2. Telford Medals and Telford Premiums to Harley Hugh Dalrymple-Hay,[2] M. Inst. C.E., for his Paper on "The Waterloo and City Railway," and to Bernard Maxwell Jenkin, Assoc. M. Inst. C.E., for his Paper on "The Electrical Equipment of the Waterloo and City Railway."
3. Telford Medals and Telford Premiums to Frederick William Bidder, M. Inst. C.E., for his description of "The Great Central Railway Extension: Northern Division," and to Francis Douglas Fox, M.A., Assoc. M. Inst. C.E., for his description of "The Great Central Railway: Southern Division."
4. A Watt Medal and a Telford Premium to John Dewrance,[3] M. Inst. C.E., for his Paper on "The Corrosion of Marine Boilers."
5. A Crampton Prize to Sir Charles Augustus Hartley,[4] K.C.M.G., M. Inst. C.E., for his Paper entitled:—"A Short History of the Engineering Works of the Suez Canal."
6. Telford Premiums to Charles Newton Russell, Assoc. M. Inst. C.E., for his Paper on "Combined Refuse-Destructors and Power-Plants," and to Reginald Arthur Tatton, M. Inst. C.E., for his Paper on "The Purification of Water after its Use in Manufactories."

[1] Has previously received a Howard Quinquennial Prize.
[2] Has previously received a Miller Prize.
[3] Has previously received a Telford Premium.
[4] Has previously received Telford, Watt, and George Stephenson Medals, Telford and Manby Premiums, and a Crampton Prize.

FOR PAPERS PRINTED IN SECTION II. OF THE PROCEEDINGS FOR THE SESSION 1899–1900.

1. A George Stephenson Medal and a Telford Premium to Leveson Francis Vernon-Harcourt,[1] M.A., M. Inst. C.E., for his Paper on "Experimental Investigations on the Action of Sea-water in Accelerating the Deposit of River-Silt and the Formation of Deltas."
2. A Telford Premium to Henry James Shedlock Heather, B.A., Assoc. M. Inst. C.E., for his Paper on "Electric-Transmission Plants at Moodie's, De Kaap Gold Fields, Transvaal."
3. A Telford Premium to Walter Rosenhain, for his Paper on "Experiments on Steam-Jets."
4. A Telford Premium to James Glover, M.A., Assoc. M. Inst. C.E., for his Paper on "Transition-Curves for Railways."
5. A Telford Premium to Alfred Barton Brady, M. Inst. C.E., for his Paper on a "Low Level Concrete Bridge over the Mary River, Maryborough, Queensland."
6. A Telford Premium to Richard Craig Farrell,[2] Assoc. M. Inst. C.E., for his Paper on "Railway Flood-Works in the Punjab and Sind, relative to the North-Western State Railway."
7. A Telford Premium to Clements Frederick Vivian Jackson, B.E., Assoc. M. Inst. C.E., for his Paper on the "Design and Construction of Steel Bridge Work, with Particulars of a Recent Example in Queensland."
8. A Telford Premium to George Blake Walker, M. Inst. C.E., for his Paper on "By-Product Coke Ovens."

FOR PAPERS READ BEFORE MEETINGS OF STUDENTS AT THE INSTITUTION.

1. The "James Forrest" Medal and a Miller Prize to Charles Beresford Fox, B.A., Stud. Inst. C.E., for his Paper on "The Construction of the Simplon Tunnel."
2. Miller Prizes to Barnard Humphrey and Henry Eoghan O'Brien, B.Sc., Students Inst. C.E., for their joint Paper on "Bearing Springs."
3. A Miller Prize to Harry Egerton Wimperis, B.A., Wh.Sc., Stud. Inst. C.E., for his Paper on "Experiments on Struts with and without Lateral Loading."

[1] Has previously received a Telford Medal and Telford and Manby Premiums.
[2] Has previously received a Miller Prize.

FOR PAPERS READ BEFORE LOCAL ASSOCIATIONS OF STUDENTS.

4. The "James Prescott Joule" Medal and a Miller Prize to Jonah Walker Smith, Stud. Inst. C.E. (Birmingham), for his Paper on the "Sewerage and Sewage-disposal of Burton-on-Trent."
5. A Miller Prize to Andrew Home Morton, Stud. Inst. C.E., (Glasgow) for his "Notes on the Laying Down of a small Works for the Production of Wrought Iron."

SUBJECTS FOR PAPERS, PREMIUMS, AND INSTRUCTIONS FOR PREPARING ORIGINAL COMMUNICATIONS.

THE COUNCIL of The Institution of Civil Engineers invite Original Communications on the Subjects included in the following List, as well as on other questions of professional interest. This list is to be taken merely as suggestive, and not in any sense as exhaustive. For approved Papers the Council have the power to award Premiums, arising out of Funds bequeathed for the purpose, the particulars of which are annexed.

LIST OF SUBJECTS.

RAILWAYS.

1. The Efficiency of Railways as affected by gauge, with reference to (*a*) the character of the traffic and climatic conditions; (*b*) utility for Military purposes.
2. The effects of Break of Gauge on the working expenses of a Railway, with reference to the cost of transfer, the liability to loss and breakage, and the necessity for increased rolling stock and separate repairing-shops.
3. The increase of Speed in express Travelling.
4. The use of Cast-Iron, Steel, and Wooden Sleepers; their suitability for various kinds of ballast, and the effects of salts contained in ballast, and of the sea air, upon them.
5. Rail-Depôts and Appliances for handling and stocking permanent-way materials.
6. The application of Machinery in large Railway Goods-Yards and Sheds.
7. The handling of Luggage by Machinery in large Passenger Stations.
8. Automatic Couplings and appliances for the Prevention of Accidents in Shunting.
9. The Maintenance, Strengthening, and Present Condition of Early Iron Bridges.
10. The Erection of Girders, with or without scaffolding.

11. The design and construction of Railway Carriages, having reference to (*a*) lavatory accommodation; (*b*) provision for refreshments; (*c*) sleeping accommodation.
12. Standard and Metre-gauge rolling-stock on Indian railways, having reference to their relative capacity for (*a*) ordinary traffic; (*b*) Military transport and the carriage of heavy guns.
13. Street Railways, having reference to different systems of traction, viz., (*a*) steam; (*b*) cable conduit; (*c*) electric trolley; (*d*) electric rail contact; (*e*) electric conduit; (*f*) electric storage battery.

Waterways and Maritime Works.

14. The most economical Methods of Handling large masses of Excavation, as exemplified in modern canal construction.
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Machinery.

19. The Design and Construction of large Turbines.
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23. The utilization of Wave- and Tide-power.
24. Modern Methods of Pumping compared with regard to cost and efficiency.
25. The Application of Compressed Air, Steam and Hydraulic power to Rock-drills and to other tools.
26. The Application of Steam-, Compressed-Air, Oil- and Gas-Engines to tractive purposes on common roads and on tramways.
27. The Theory and Development of the Compound Steam-Turbine.
28. The Strength of Steel Shafts, Tubes and Cylinders.
29. The most suitable Alloys for the Working Parts of Pumps for lifting Corrosive Liquids from mines, etc.

30. The Methods of Preventing or Arresting the Corrosion of Hydraulic Rams of large diameter.
31. The Methods of Testing the Lubricating Values of Oils, Greases, etc.
32. The Use of the Die-press in workshop operations.
33. The Utilization of Heat (*a*) generated in the compression of air and other gases; (*b*) carried away by steam-engine condenser-water; and (*c*) contained in boiler-furnace flue-gases.
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Mining and Metallurgy.

38. The Sinking of Shafts through Various kinds of Strata, including Sand, and the methods of dealing with large inrushes of water.
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40. Mining-Machinery, inclusive of Compound Engines for Winding purposes.
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Shipbuilding.

63. The Use of Steel of great tensile strength in Ships.
64. The present Limits of Speed at Sea.
65. The Relative Advantages of Single Screws, of Twin Screws, and of Triple Screws in large vessels.
66. The best position for Torpedo-Discharging Tubes on large vessels, with a fixed direction, or trainable.

Waterworks, Sewerage and Gasworks.

67. The Use of Steel in the Construction of large Tanks.
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71. The methods of Conveying and of Using Natural Gas.
72. The Use and Durability of Cast-iron Pipes and of other structures in contact with various soils.

APPLICATIONS OF ELECTRICITY.

73. The Use of Electric Energy in working Mines.
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76. The first cost and economy of operation of Electric Traction on Railways with heavy trains.
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81. The Progress of Telegraphy and Telephony at home and abroad.
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PREMIUMS.

1. The TELFORD FUND, left "in trust, the Interest to be expended in Annual Premiums, under the direction of the Council." This bequest (with accumulations of dividends) produces a gross amount of £235 annually.

2. The MANBY DONATION, of the value of about £10 a year, given "to form a Fund for an Annual Premium or Premiums for Papers read at the meetings."

3. The MILLER FUND, bequeathed by the testator "for the purpose of forming a Fund for providing Premiums or Prizes for the Students of the said Institution, upon the principle of the 'Telford Fund.'" This Fund (with accumulations of dividends) realises nearly £140 per annum. Out of this Fund the Council has established a Scholarship,—called "The Miller Scholarship of The Institution of Civil Engineers,"—and is prepared to award one such Scholarship, not exceeding £40 in value, each year, and tenable for three years.

4. The HOWARD BEQUEST, directed by the testator to be applied "for the purpose of presenting periodically a Prize or Medal to the author of a treatise on any of the Uses or Properties of Iron or to the inventor of some new and valuable process relating thereto, such author or inventor being a Member, Graduate, or Associate of the said Institution. The annual income amounts to nearly £15. It has been arranged to award this prize every five years commencing from 1877. The next award will be made in 1902.

5. The CRAMPTON BEQUEST of £500, free of legacy duty, has been invested in the purchase of £512 15*s.* 11*d.* 2¾ per cent. consols, and the income arising therefrom is now £13 14*s.* This trust is for the purpose of founding "a Prize to be called the 'Crampton Prize,' so that the interest of the said legacy shall be annually expended in a medal or books or otherwise for presentation to the Author of the best Paper on 'The Construction, Ventilation and Working of Tunnels of Considerable Length,' or failing that then on any other subject that may be selected."

6. The balance of the TREVITHICK MEMORIAL FUND, amounting to £100 0*s.* 9*d.*, has been accepted for a periodical Premium to be called after Richard Trevithick. This sum has been placed in £103 2¾ per cent. consols, upon which the interest is £2 15*s.* a year.

7. The JAMES FORREST MEDAL, founded in 1897, is endowed with the balance of a sum of money given by those who had served on the Council towards a presentation to Mr. Forrest on his retirement from the Secretaryship. The medal is awarded annually to a Student of the Institution who contributes the best Paper received from that class.

8. The JAMES PRESCOTT JOULE MEDAL is placed by the Trustees of the Endowment Fund at the disposal of the Council, in every third year, for award to a Student of the Institution, for the best Paper presented on an engineering subject, "preference being given to a Paper dealing with the transformation of energy." The medal will be at disposal next in 1903.

The Council will not make any award unless a communication of adequate merit is received, but will give more than one Premium if there are several deserving memoirs on the same subject. In the adjudication of the premiums no distinction will be made between essays received from members of the Institution or strangers, whether Natives or Foreigners, except in the cases of the Miller and the Howard bequests and the James Forrest and James Prescott Joule medals, which are limited by the donors.

No Paper will be received from a Student in competition for a Premium when he has become qualified by age, viz. twenty-five years, for election into the Corporation. Students' Papers to be read before local Associations of Students of the Institution, in competition for Premiums, must be sent to the Institution, for registration, *before* being read.

Instructions for Preparing Original Communications.

In writing these Essays the use of the first person should be avoided. They should be legibly written on foolscap paper, on one side only, leaving a margin on the left side, in order that the sheets may be bound. Every Paper must be prefaced by an Abstract of its contents not exceeding 1,500 words in length.

Illustrations should be drawn on drawing- or tracing-paper, and figured dimensions should be introduced only where necessary. When an illustrated communication is accepted for reading, a series of Diagrams will be required so drawn and coloured as to be clearly visible at a distance of 60 feet. These diagrams will be returned.

Papers which have been read at the Meetings of other Societies, or have been published, will not be accepted. According to the By-laws every Paper presented to the Institution is deemed to be its property, and may not be published without the consent of the Council.

The Communications must be forwarded to the Secretary, from whom any further information may be obtained. There is no specified date for the delivery of MSS., as when a Paper is not in time for one session it may be dealt with in a subsequent one.

James Forrest, *Honorary Secretary*,
J. H. T. Tudsbery, *Secretary*.

The Institution of Civil Engineers,
Great George Street, Westminster, S.W.
July, 1901.

EXCERPT BY-LAWS, ARTICLE 3, SECTION XV.

"Every Paper, Map, Plan, Drawing, or Model, presented to the Institution shall be considered the property thereof, unless there shall have been some previous arrangement to the contrary, and the Council may publish the same in any way and at any time they may think proper. But should the Council refuse or delay the publication of such Paper beyond a reasonable time, the Author thereof shall have a right to copy the same, and to publish it as he may think fit, having previously given notice, in writing, to the Secretary of his intention. Except as hereinbefore provided, no person shall publish, or give his consent for the publication of any communication presented and belonging to the Institution, without the previous consent of the Council."

NOTICE.

It has frequently occurred that in Papers which have been considered deserving of being read and published, and have even had Premiums awarded to them, the Authors have advanced somewhat doubtful theories, or have arrived at conclusions at variance with received opinions. The Council would therefore emphatically repeat that the Institution as a body must not be considered responsible either for the statements made, or for the opinions expressed in the Papers or in the consequent Discussions; and it must be understood that such Papers may have Medals and Premiums awarded to them, on account of the Science, Talent, or Industry displayed in the consideration of the subject, and for the good which may be expected to result from the inquiry; but that such notice, or award, must not be regarded as an expression of opinion, on the part of the Institution, of the correctness of any of the views entertained by the Authors of the Papers.

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Glasgow University.
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Government Statistician, Sydney.
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Graham, John.
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Grinlinton, F. H.
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H.

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"Hardware Trade Journal, The."

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Hart, *Sir* R., *Bart.*
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Incorporated Institution of Gas Engineers.
India Office.
"Indian and Eastern Engineer."
"Indian Engineering."
Indian Telegraph Department.
"Industria, L'."
"Industrie électrique, L'."
"Ingegneria Civile e le Arti Industriali, L'."
"Ingeniero, El."
Institute of Marine Engineers.
Institution of Civil Engineers of Ireland.
Institution of Electrical Engineers.
Institution of Engineers and Shipbuilders in Scotland.
Institution of Mechanical Engineers.
Institution of Mining Engineers.
Institution of Naval Architects.
Institution of Surveyors, Sydney.
Instituto de Injenieros de Santiago de Chile.
International Railway Congress.
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J.

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Jenkins, H. C.
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Johnson, J. B.
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K.

Kaiserliche königliche technische Hochschule in Brünn.

Kaiserliche königliche technische Hochschule in Graz.
Kaiserliches Patentamt.
Keefer, T. C.
Kempe, H. R.
Kennedy, J.
Kennedy, N.
Kernot, M. E.
Kew Observatory.
King's College, London.
Königliche bayerische Akademie der Wissenschaften zu München.
Königliche Gesellschaft der Wissenschaften zu Göttingen.
Königliche sächsische technische Hochschule zu Dresden.
Königliche technische Hochschule zu Aachen.
Königliche technische Hochschule zu Berlin.
Königliche technische Hochschule in Stuttgart.
Koninklijk Instituut van Ingenieurs.
Kraus, J.

L.

Larard, C. E.
Larminie, J. C.
Lass, A.
Latham, B.
Leeds Free Public Libraries.
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Lindley, W. H.
Lisbôa, A.
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Longridge, M.
Louis, D. A.
Lovegrove, E. J.
Luiggi, L.

M.

McCullough, E.
M'Donald, A. B.
McGill College and University, Montreal.
McLean, W. N.
MacLeod, H. A. F.
McPherson, J. A.
"Machinery Market."
Madras University.
Maginnis, A. J.
Magyar Mérnök-és Épitész.
Mallet, A.
Manchester Association of Engineers.
Manchester Literary and Philosophical Society.
Manchester Steam Users' Association.
Manitoba University.
"Marine Engineer."
"Mariner."
Massachusetts Institute of Technology.

Massachusetts State Board of Health.
Mawbey, E. G.
Mayer, A.
Mayne, C.
Mazoyer, C. M.
"Mechanical Engineer."
"Mechanical World."
"Mechanical Progress."
Melbourne University.
"Memorial de Artillería."
Merchants' Association of New York.
Mersey Docks and Harbour Board.
Meteorological Department of the Government of India.
Meteorological Office, Bombay.
Meteorological Office, London.
Meteorological Service of Canada.
Metropolitan Board of Water Supply and Sewerage, Sydney.
Metropolitan Water Board, Boston, U.S.A.
Michigan University.
Middleton, W.
Midland Institute of Mining, Civil and Mechanical Engineers.
Military Service Institution, U.S.A.
Miller, T. L.
Mines and Water Supply Department, Melbourne.
"Mining Engineering."
Mining Institute of Scotland.
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Ministère de la Marine, Paris.
Ministère des Chemins de Fer, Postes et Télégraphes, Brussels.
Ministère des Travaux publics, Paris.
Ministerie van Waterstaat, Handel en Nijverheid.
Ministerio dei Lavori Pubblici, Rome.
"Model Engineer, The."
Moncrieff, J. M.
Moore, R. St. G.
Morison, D. B.
Morison, G. S.
Morton, D. H.
Mouchel, L. G.
Mountain, A. C.
Moutier, A.
Muthesius, H.

N.

Napier (N.Z.) Harbour Board.
Nares, *Vice-Admiral Sir* G. S.
National Physical Laboratory.
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Navy Department, U.S.A.
New York State Board of Health.
New Zealand Institute.
New Zealand University.
Newbigging, T.
Newcastle-upon-Tyne Public Libraries Committee.
Norris, W.
North-East Coast Institution of Engineers and Shipbuilders.
North of England Institute of Mining and Mechanical Engineers.
Nova Scotian Institute of Science.
Nyströmer, C.

O.

O'Callaghan, F. L.
Oesterreichischer Ingenieur-und Architekten-Verein.
Oficina Meteorológica Argentina.
Ordnance Committee.
Otagawa, M.
Owens College, Manchester.

P.

Pacchioni, A.
"Paper Maker."
Parry, J.
Parry, J. W.
Parshall, H. F.
Parsons, *Hon.* C. A.
Patent Office.
Peabody Institute.
Peckitt, R. G.
Pennsylvania Railroad Company.
Permanent-Way Institution.
Perrin, C.
Perry, J.
Pharmaceutical Society of Great Britain.
Phillips, E. A. W.
Phillips, R.
"Phillips' Monthly Register."
Philosophical Society of Glasgow.
Pilkington, H.
"Plumber and Decorator."
"Politecnico, Il."
Polyteknisk Forening.
Popplewell, W. C.
Port Captain of Natal.
Porter, R. C.
"Portfeuille économique des Machines."
Post, J. W.
Poul la Cour, —.
Pourcel, A.
"Practical Engineer."
"Progressive Age."
"Przegląd Techniczny."
"Public Health Engineer."
Public Works Department, Bengal.
Public Works Department, Bombay.
Public Works Department, Madras.
Public Works Department, Ottawa.
Public Works Department, Simla.
Public Works Ministry, Cairo.
Puig de la Bellacasa y Sanchez, N.
Pullen, W. W. F.

Q.

"Quarry, The."
Queen's College and University, Kingston, Canada.
Queen's College, Belfast.
Queen's College, Cork.
Queensland Branch of the Royal Geographical Society of Australasia.
"Queen's Quarterly."

R.

Radcliffe Library, Oxford.
Railroad Commissioners of Massachusetts.

"Railway and Shipping Contractor."
Railway Commissioners of New South Wales.
"Railway Engineer, The."
"Railway Master Mechanic."
"Railways."
Reade, T. M.
Reale Accademia dei Lincei, Rome.
Reale Instituto d'Incoraggiamento di Napoli.
Reale Istituto Lombardo di Scienze e Lettere.
Regio Ispettorato Generale delle Strade Ferrate.
Regio Istituto Tecnico Superiore di Milano.
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Rigby, H. P. B.
Rio de Janeiro Observatory.
Rodda, J. T.
Ross, D. J.
Rowan, A. H.
Rowan, F. J.
Royal Agricultural Society of England.
Royal Artillery Institution.
Royal Astronomical Society.
Royal College of Science for Ireland.
Royal Colonial Institute.
Royal Commission, Paris Exhibition, 1900.
Royal Dublin Society.
Royal Engineers Institute.
Royal Geographical Society.
Royal Geographical Society of Australasia.
Royal Institute of British Architects.
Royal Institution.
Royal Irish Academy.
Royal Meteorological Society.
Royal Photographic Society.
Royal Society of Edinburgh.
Royal Society of London.
Royal Society of New South Wales.
Royal Statistical Society.
Royal United Service Institution.
Royal University of Ireland.
Rundall, J. W.
Rust, C. H.

S.

Sächsischer Ingenieur- und Architekten-Verein.
Saetren; G.
Sanitary Institute.
Sauvage, E.
Sawyer, F. H.
Schönberg, A. C.
School of Mining, Kingston, Ontario.
Schreiber, C.
Schweizerischer Ingenieur- und Architekten-Verein.
"Science and Art of Mining, The."
Shipmasters' Society.
"Shipping World."
Shoolbred, J. N.
Silk, A. E.
Sinigaglia, F.
Smithsonian Institution.
Sociedad Científica Argentina.

Società degli Ingegneri e degli Architetti in Torino.
Società degli Ingegneri e degli Architetti Italiani.
Société anonyme John Cockerill.
Société d'Encouragement pour l'Industrie nationale.
Société de l'Industrie minérale de St. Etienne.
Société des Ingénieurs civils de France.
Société industrielle de Mulhouse.
Société nationale des Chemins de fer vicinaux, Brussels.
Société nationale des Sciences naturelles et mathématiques de Cherbourg.
Société scientifique industrielle de Marseille.
Société technique de l'Industrie du Gaz en France.
Society of Arts.
Society of Chemical Industry.
Society of Engineers.
South African Association of Engineers and Architects.
South African Philosophical Society.
South Australian Railways Commissioner.
South Australian School of Mines and Industries.
South Wales Institute of Engineers.
Sowerby, W.
Spolku Architektů a Inženýrů v království Českém.
Spon, E. and F. N.
Spooner, H. J.
Spring, F. J. E.
Stanley, W. F.
State Agricultural College of Colorado.
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Stewart, C. E.
Stothert, P. K.
Street Department, Boston, U.S.A.
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Stromeyer, C. E.
Surgeon-General, U.S. Army.
Survey Department, Ceylon.
Survey of India Department.
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Surveyors' Institution.
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Sydney Observatory.
Sydney University.

T.

Tasmanian Government Railways Department.
Tatton, R. A.
Technischer Staatslehranstalt in Chemnitz.
Teknisk Forening, Copenhagen.
Thomason Civil Engineering College, Roorkee.
Thomson, T. F.
Thresh, J. C.
Thurston, R. H.
Timonoff, V. E. de.
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Trevithick, R. F.
Trinity University, Toronto.

U.

Uhagon, R. de.
Union Internationale Permanente de Tramways, Brussels.
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United States Artillery School.
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United States Naval Institute.
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University College, Bristol.
University College, Liverpool.
University College, London.
University College, Nottingham.
University College, Sheffield.
Upsala University.
Utah Agricultural College.

V.

Vacher and Sons.
Vauthier, L. L.
Verein deutscher Eisenhüttenleute.
Verein deutscher Ingenieure.
Verein für Eisenbahnkunde zu Berlin.
Vernon-Harcourt, L. F.
Victoria University, Manchester.
Victoria University, Toronto.
Victorian Railways Commissioner.

W.

Wallace, J. F.
Wallace, R. W.
Wallis, H. S.
Wallis-Tayler, A. J.
Walther-Meunier, —.
War Department, U.S.A.
Ward, L. B.
Ward-Smith, W.
"Water."
Watson, J.
Webster, G. S.
Webster, W. R.
Western Society of Engineers, Chicago.
Wheeler, W. H.
Whipple, G. C.
Whitaker, W.
White, C. A.
Whyatt, H. G.
Williamson, J. B.
Wingfield, C. H.
Wolverhampton Free Library.
Worrall, E.

Y.

Yorkshire College.

Z.

Zeman, J.

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Watson, J. W. . .	1	1	0
Williams, J. H. .	2	2	0
Wolseley-Lewis, F. T.	3	3	0
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Wynne-Edwards, H. C.	2	2	0
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EXTRA MEETING.

25 April, 1901.

JAMES MANSERGH, President,
in the Chair.

THE "JAMES FORREST" LECTURE.

THE CHAIRMAN reminded the members that this series of lectures had been instituted by Mr. James Forrest, who, for between 40 years and 50 years, had been the able and energetic Secretary and chief officer of the Institution. A fund had been raised by contributions from the members as a personal testimonial to him; but, having always the interests of the Institution at heart, Mr. Forrest had suggested that some part of the fund should be allocated towards the expenses of a series of lectures, in the shape of a nominal fee to the lecturer. It was needless to say that all the lecturers had undertaken the task mainly out of respect to Mr. Forrest and goodwill to the Institution. The foregoing eight lectures had been delivered by eminent men, the first by the late Sir William Anderson, the second by Dr. John Hopkinson, whose tragic death was so deeply deplored by all, the third by Professor Unwin, the fourth by Dr. Kennedy, the fifth by Dr. Sims Woodhead, the sixth by Professor Boyd Dawkins, the seventh by Professor Ewing, and the eighth by Sir William Preece. The Institution was deeply grateful to those gentlemen for the trouble they had taken in preparing and delivering them. It was probably well known that Mr. Forrest's interest in the Institution and its individual members was not at all abated. A year ago the Chairman had received from him a most sympathetic, though not quite unpainful, reminder that his name had been on the books for 40 years. Probably some gentlemen present had had a similar intimation. He was sorry to say that Mr. Forrest was then suffering from an attack of influenza, but he was sure the members would wish he might soon be restored to that health which would enable him to enjoy his well-earned repose.

The Chairman then introduced the lecturer, Dr. Frank Clowes, Chemical Adviser to the London County Council, who delivered the following lecture :—

"Chemistry in its Relations to Engineering."

By Professor FRANK CLOWES, D.Sc. Lond.

INTRODUCTORY.

KNOWING as much as an outsider may know of the invaluable services which have been rendered to the Institution of Civil Engineers and to a great profession by the former Secretary, James Forrest, it is to me a source of gratification that I am placed in a position to contribute in any degree to the preservation of the memory of these long-maintained and distinguished services. And I confess that this consideration added considerably to the pleasure which I felt in accepting the complimentary invitation of the Council of the Institution to deliver the Forrest memorial lecture for the present year. The success of an Association is always to a large extent dependent upon the character and work of its Secretary, and when that officer enters into his duties, not only with energy and zeal, but with enthusiasm and knowledge, the advantage resulting to the Association from his services cannot well be over-estimated.

GENERAL STATEMENT OF SUBJECT.

I am invited to speak to-night of the relations to Engineering, in its broadest sense, of the science of chemistry, a science to which I have thus far devoted my life and energy. Accepting the broad definition of the engineer as one whose function it is to utilize the forces of Nature in the interests of mankind, it will at once be manifest that the engineer is largely interested and concerned in the principles of chemical science.

Of the several natural forces of which he has to take advantage, the chemical force will be the one with whose action and products the engineer is perhaps most constantly brought into relation. There can be no doubt that in proportion as he is conversant with chemical laws and facts, and is able to readily bring himself into touch with chemists and with chemical thought and progress, the engineer's work must be greatly facilitated, and he will be saved from many mistakes and failures to which he might otherwise be subject. But it is also equally true that the chemist who is concerned with

the application of his science to manufacturing and engineering purposes usually reaps equal advantage from some knowledge of the principles of engineering.

If we consider only the careers of the engineers of bygone times, it might appear that the great engineer, like the poet, is born and not made. And this must always be true in a great degree of a man who distinguishes himself in any art or science, whether pure or applied. The qualities of accurate perception, energy, industry, common sense, and self-reliance, which are amongst the sterling requirements for success in almost any career, were undoubtedly those upon which the earlier engineers mainly depended, rather than upon any course of special training or education. And it would probably not be denied that these qualities are as essential at the present day as they have been in the past. But those whose success depended upon the possession of these qualities, and who had not received the additional advantage of being able to draw to the full from the accumulated wisdom expressed in scientific laws and principles, and who had not been trained to carry out themselves or through others the experimental inquiries necessary to advance knowledge—these men would have been the first to acknowledge the disadvantage at which they were placed, and the loss of time and of success from which such knowledge might have saved them.

Chemistry in Engineering Curriculums.

It is gratifying, therefore, to find that acknowledgment in some degree is made of these facts in the training which engineering students now receive in our educational institutions before they start upon their active career. And perhaps one of the most striking evidences of the recognition of the importance of organised and special training being given to those who intend to adopt the profession of engineering, is the fact that the more progressive and the newly-constituted universities are prepared to grant degrees in engineering science. Thus, the London, Victoria and Birmingham Universities, and the University of Wales, are following the lead of Cambridge and of the Scottish and Irish Universities in this respect.

The engineer of 50 years ago can hardly be said to have received any special educational training; he forced himself to the front in virtue of his qualities and industry alone. But the youth who to-day intends to become an engineer feels it wise, if not necessary, to decide where he shall receive not only his general but also his

engineering education. While he was at school he will have learnt much about the simpler and more general laws and facts of mechanics and natural science, both by description and by practical work in the laboratory and in the workshop; he will also have attained to some proficiency in mathematics, in one or more of the modern languages, in drawing and in other usual school subjects. When he passes on to his college career his knowledge of these subjects will undergo expansion in the class-room and especially in the laboratory and workshop. It is satisfactory to find that many of our leading schools for training engineers exist in connection with institutions in which pure and applied mathematics, natural science, and modern languages are efficiently taught even in their higher stages. The engineering student is thus afforded the opportunity of following up the higher study of any one of these subjects, if his taste and energy lead him to wish to do so. But even his ordinary course of instruction always includes the opportunity of obtaining lecture and laboratory instruction in chemistry.

It fell to my lot some years ago, as principal of one of our large provincial colleges, to assist in organising a new department of engineering instruction, and it was necessary to visit some of the engineering schools of the Metropolis, with the view of studying and comparing the engineering curricula which they offered. In the prospect of giving the present lecture I have had the further advantage of conferring with the teachers of several representative educational institutions which train engineering students. These institutions were chosen more or less at random, but they probably afford a fair average estimate of the amount of time and attention which is given to the chemical instruction of engineering students. The information may be summarised as follows:—

Cambridge University.—Engineering students enter for the Mechanical Sciences Tripos Examinations. Chemistry is not included in these examinations, and, as a rule, the candidates do not study chemistry. But they have the opportunity of studying chemistry during their course, or of taking the Natural Sciences Tripos before they enter for the Mechanical Tripos, or of remaining in the University for a fourth year, after taking the Mechanical Tripos, and then studying chemistry as a principal subject.

Durham University.—During the first year all engineering students take the full first year's lecture course of the chemical curriculum, together with 6 hours per week in the chemical laboratory. Chemistry is an optional subject in the second and third years. In their second year mining engineers take 2 days

in the chemical laboratory; and, in the third year, lectures and laboratory work in metallurgy and assaying, 2 days a week being allotted to laboratory work.

The Victoria University:—

(i) *The Owens College, Manchester.*—The teaching of chemistry is not included as a compulsory subject for engineering honours. In the first year three lectures on chemistry per week may be taken, together with 4 hours in the chemical laboratory. Most men take this instruction.

(ii) *The Yorkshire College, Leeds.*—Three chemistry lectures per week may be taken in the first year, but this is not compulsory. No practical work in the chemical laboratory is required.

(iii) *University College, Liverpool.*—The engineering curriculum provides for two lectures, and from 1½ hour to 2 hours per week in the laboratory, during two terms of the first year. In the second year 1½ hour's instruction in metallurgy per week is provided. Additional chemical instruction is optional and is not often taken.

King's College, London.—Engineering students attend a minimum of 72 hours' lectures in the first session, and of 126 hours in the laboratory in the second session. An option is given of attending the laboratory two or three times a week in the third session, but this is not often taken advantage of. Special arrangements are made, between the chemical and metallurgical departments, for the work of students in mining engineering.

University College, London.—The full engineering course includes four chemistry lectures per week for two terms in the first year, and 2 hours a week in the chemical laboratory during two terms in the third year.

Central Technical College, London.—In the first year's engineering curriculum, instruction in chemistry is given during 16 weeks for 13 hours per week. Of this time 2 hours are devoted to lecture, 2 hours to class, and 9 hours to laboratory work. In the second year 2 hours per week, or about 60 hours in all, are devoted to lectures, and 15 afternoons to laboratory work.

Mason College, Birmingham.—Instruction is provided both by chemical lectures and by chemical laboratory work in the first year's engineering course; this includes 3 hours' lecture per week for the session, and 3 hours' laboratory work during the first term.

University College, Nottingham.—Two lectures per week in the first year, together with 1¾ hour's chemical laboratory work, are included in the engineering curriculum.

University College, Sheffield.—In the first year's engineering

curriculum, 1 hour for chemistry lecture and 1 hour for chemical laboratory work per week are included.

St. Andrews University.—Students of University College, Dundee, who are preparing to take the B.Sc. degree in engineering attend a course of 100 lectures on elementary chemistry, and spend 100 hours in the chemical laboratory.

Glasgow University.—Students attend the winter course of 100 lectures and 2½ months at least in the laboratory, working 2 hours a day. They make inorganic preparations, and go through a course of analytical work, including testing for single substances and mixtures. A student who takes a 5-months' course does quantitative work.

Edinburgh University.—Engineering students take the full chemistry course of 100 lectures, including about twenty on organic chemistry. They attend fifty meetings of the laboratory class of 1 hour each, learning to test for simple salts, making simple inorganic preparations, and doing some rudimentary volumetric work. Fuller laboratory work is optional.

Trinity College, Dublin.—Chemical instruction is given to engineering students in their first and second years.

In the first year, during the first term they attend about eighteen lectures on general elementary chemistry, and carry out in the chemical laboratory experimental work relating to combustion and general oxidation and reduction. In the second term the metals and elementary metallurgy are studied in eighteen lectures, and in the laboratory some metallic compounds used in engineering are examined and the systematic tests for metals are learned.

In their second year some 60 hours are devoted to work in the chemical laboratory; this includes the qualitative analysis of mixtures and the valuation of metal ores, the assay of lead and gold, the determination of hardness in water and of combined carbon in steel, the examination of white-lead, of lubricants and of cement, and the use of Thompson's calorimeter.

Queen's College, Belfast.—Engineering students attend a course of about 100 lectures on chemistry during their first year, and a 3-months' course of practical chemistry during their second year. They are examined on these subjects at the Royal University of Ireland in their first and second examinations for the degree of Bachelor of Engineering (B.E.).

[It may be noted in this connection that the examinations prescribed by the Institution of Civil Engineers for the admission of Students and for the election of Associate Members include portions of chemistry as optional subjects only; but the syllabuses

given under Metallurgy and under Thermo- and Electro-chemistry appear to be very satisfactory as far as they go.]

I wish to express my thanks to the many professors of engineering and chemistry who have furnished the above statistics. Some of the opinions to which they gave expression in their letters may be usefully quoted, and are appended below. The different individuals are distinguished by letters of the alphabet.

A. "The course to be covered by engineering students is so full that I am doubtful whether more time could be usefully given to chemistry, save in exceptional cases where students desire to take up special branches of chemical engineering. There can be no doubt, however, that there is a large field for chemists devoting themselves to the needs of engineers. The chemistry of engineering is a business in itself; but chemists rather than engineers are the more likely people to develop on these lines. This, however, is probably a matter of opinion."

B. "Every manufacturing process in civil, mechanical, and electrical engineering may be improved, and has actually been improved in the past, by a knowledge of chemistry. . . . Lectures on chemistry are of little good unless the student works numerical examples on the weights and volumes in all sorts of reactions, and does both qualitative and quantitative analysis in the laboratory."

C. "The first year's work is, of course, introductory and general, but consists largely of simple qualitative exercises. I do not teach the ordinary qualitative test-tubing. In the second year the students do water analysis, copper in brass, etc. The second year's lectures are made as practical as possible, much attention being given to fuel, alloys, etc. But our chief attempt is to make our students thinking, reasoning beings in the first year—in other words, to cure them of the bad habits acquired at school."

D. "Formerly chemistry, including laboratory work, was an essential part of our course, but with my consent and approval, and indeed partly on my initiative, the compulsion was removed. I found that the attempt to give engineers the preliminary knowledge ideally desirable, viz., mathematics, physics, chemistry and geology, simply resulted in their not doing any of the subjects properly, and relief seemed necessary. Chemistry, being the least needful subject, was cut off. I believe the arrangement is the best one for present circumstances. It is, however, far from being ideal, and no doubt the day will come when no self-respecting engineer will be ignorant of the general principles of chemistry, and no mechanical engineer will be unable, as is now usually the case, to understand or discuss the chemistry and thermo-chemistry

of fuel. However, with no organised secondary education, with a country full of ignorant and obstinate parents, and with the strong prejudices of self-styled 'practical' men, we shall have to wait some time, I fear, before we can have in operation anything like an ideal course of teaching for engineers."

E. "Engineering does not figure as a subject required of students taking chemistry as a chief subject for the B.Sc., nor do I think it should do so, as 3 years' study of chemistry, with physics as another subject, is little enough to give a man a good knowledge of chemistry. Engineering is no doubt of value to the technical chemist, but you cannot turn out a technical chemist in 3 years. What I feel that we want in England in order to enable the University Colleges to do the best for the country is a supply of well-educated youths of the age of 17, fitted to take up the special science training which the University Colleges are prepared to give. The secondary schools do not do this, but try to turn out specialists at the age of 17 or even younger, instead of youths with a thoroughly sound general education in a position to benefit by the special education, such as is needed for their after-life career. I have a feeling that engineers in general neglect chemistry, and many of them, whom I know, have very hazy notions of such fundamental phenomena as those of combustion."

F. "Chemical instruction is seldom taken by our engineering students. I am at a loss to know whether they consider it above them or beneath them. They prefer to obtain empirical knowledge rather than to cultivate self-thinking."

The general opinion, as far as it may be gathered from the information furnished by these various educational institutions, seems to be somewhat as follows:—

1st. The study of chemistry, both theoretical and experimental, by the engineering student is highly desirable, and should be made compulsory, if possible. Accordingly, most of the institutions provide time for the study of chemistry in their engineering curricula; a few give much attention and time to training the engineering student in general chemistry; while a small minority feel that they must be content for the present to recommend the study without making it compulsory.

2nd. Regret is generally expressed that the engineering curriculum is too full to permit of a much more satisfactory chemical training being insisted upon.

3rd. Especial stress is laid on the value of experimental work in the chemical laboratory.

4th. The general curriculum should include:—

The experimental demonstration of general chemical laws and principles, as illustrated by a study of some of the more common elements and compounds.

The chemical nature of pure and natural water; the relation of hard water to the waste of soap and to the production of boiler-scale, and the explanation of softening processes.

The chemical nature of air, and of the changes which are produced in it by breathing and by combustion.

The composition of fuel—gaseous, liquid, and solid; the chemical study of combustion in air, both complete and incomplete, and of the products which are formed; a similar study of the common explosives and their products.

The general principles of thermo-chemistry and of calorimetry. The general methods employed in smelting metal ores, and in making alloys.

Simple qualitative and quantitative analysis, including an experience sufficient to enable the student to understand the results of the analyses of natural water, of sewage and sewage effluent, of fuel, of flue gases, of lubricating oils, of cement, bricks, and building stones, and of iron, steel, and the common alloys.

It appears to be the general feeling of those who have had experience in teaching chemistry to engineering students, that it is useless to attempt very much in the small amount of time which can be allotted to the subject in the regular curriculum; it is evidently felt, however, that a student who wishes to attain to any considerable proficiency in the subject should be encouraged to join certain additional courses which are included in the ordinary chemical curriculum.

Probably all that can be expected of the average engineering student is that he shall become generally conversant, during his college course, with chemical language, with chemical principles and laws, and with the chemical nature of the materials with which he has to deal; and that he should obtain such an insight into chemical analysis as to be able to confer with the trained chemist, and to understand the meaning of a general statement of the results of chemical analyses bearing on metals, alloys, fuel, lubricants, cements, and other materials which are frequently used by the engineer.

It is beyond question that the engineer has too many calls upon his time and energy, both in his training and in his subsequent career, to allow of his becoming a chemist or a chemical analyst;

but he should at least be sufficiently conversant with the science to enable him to appreciate the important bearings of chemistry on his varied requirements, and to enable him to avail himself intelligently of the results of chemical investigation and analysis. He should be able to watch and to appreciate any chemical inquiry and investigation, even if he is not qualified to suggest its methods of procedure or to carry it out himself.

It has been stated to me by a German manager of large English works, who has frequently occasion to call in the professional advice and assistance of both engineers and chemists, and who is himself well educated in both departments, that he has to lament in this country the "absence of useful engineering knowledge among chemists, and of useful chemical knowledge among engineers." Another informant states that Germany employs many more trained chemists working in conjunction with her engineers than England does.

This apparently gives a clue to the way in which difficulties arising from the above causes may best be obviated. The full training of the chemist and of the engineer is a lengthy and costly process, and neither has much time or opportunity, therefore, for mastering more than his own curriculum of study, and obtaining his own special and very varied experience. In order to secure the greatest measure of success and progress, the engineer and chemist should, therefore, far more frequently confer and collaborate on an equal footing; and in order to enable them to do this successfully, the chemist who has to deal with the applications of his science may reasonably be expected to master some of the elements of engineering, and the engineer to master the elements of chemistry. Neither must then feel that he is independent of or superior to the other. Both must be willing to co-operate on equal terms in order to save the serious mistakes and failures which must inevitably arise from attempts to act on knowledge or experience of an incomplete and inadequate nature.

Illustrations of Chemistry Applied to Engineering.

In order to illustrate some of the advantages which engineers have derived from chemical coadjutors, one or two instances may be selected from different fields of engineering activity and enterprise.

Constructive materials—Cheap Steel.—In the matter of supplying the e[illegible] with suitable constructive materials, the most

striking case is that of the introduction of cheap steel of varying qualities in substitution for costly steel and other less suitable forms of iron. The original production of Bessemer steel from the purest Swedish cast iron was undoubtedly suggested by accurate chemical analyses which showed the relative chemical composition of cast iron, wrought iron, and steel. It was seen that the old lengthy and costly processes of converting cast iron into wrought iron and wrought iron into steel might be curtailed and made far less costly by converting suitable cast iron directly into steel by a single process. It was further seen that this process must consist in burning out carbon to a suitable extent from the cast iron. When Bessemer first attempted to accomplish this by blowing air through the molten cast iron, he obtained a product which was too infusible and pasty to be poured out of the "converter." This difficulty was surmounted by adopting a suggestion of Mushet's, founded again on the results of chemical analysis. It was shown by chemical analysis that the product was pasty because the carbon had been removed to too great an extent. Mushet accordingly suggested the introduction of a proper amount of molten cast iron, rich in carbon, into the decarburised product, the amount added being sufficient to raise the carbon content of the steel to the required point. The resulting steel was fluid, and was easily poured out of the Bessemer converter into the ingot moulds.

The Bessemer process therefore owed its original suggestion, as well as its salvation from failure, to the chemical knowledge which was supplied to those who were interested in the procedure. But it further owed the extension of its application to all the commonest, cheapest, and most abundant kinds of impure English cast iron to the further utilisation of chemical knowledge and suggestion.

The presence of phosphorus in cast iron in any appreciable proportion was found to render such iron unfit for conversion into steel by the Bessemer process. It was for this reason that the pure Swedish iron had to be imported into this country at considerable cost for the production of Bessemer steel, while the vast amount of iron produced in this country could not be used by Bessemer at all on account of its containing phosphorus which could not be removed during the decarburising process. Messrs. Thomas and Gilchrist proved that the British pig-irons could be converted into good steel if they were treated by the Bessemer process in the presence of basic substances such as lime and magnesia, since under these circumstances their phosphorus was

eliminated. This improvement meant that it was no longer necessary to import the relatively pure Swedish iron for the preparation of steel. The home supplies of the metal could be used for this purpose and could be made to furnish good steel at a much smaller cost than when the imported iron was used.

The vast importance of these successful applications of chemical knowledge and principles was soon felt. The engineer had the advantage of being able to employ a comparatively strong and easily-worked material for building guns, bridges, ships and large structures generally, as well as for laying down railway and tramway tracks. He was not slow to avail himself of the advantage thus secured; and we have instances in the Forth Bridge, the Tower Bridge, and in all our large merchant steamers and men-of-war and their equipment, as well as in our modern warehouses and large buildings, of the successful use of cheap steel. The advantages of increased durability and strength have thus been secured, together with decreased weight, to the great advantage of the public at large.

At the present time the metallurgical chemist and the chemical metallurgist are engaged in furnishing metals and alloys new to commerce, which can rank in importance with cheap steel, only in a somewhat minor degree; and the engineer in every department of his activity is now continually having placed at his disposal alloys which are more suitable for his various designs than any which he has hitherto employed.

Gas-Making and Gasworks.—It is scarcely necessary to point out the absolute necessity of chemical knowledge and chemical advice to the gas engineer. The engineer who designs and superintends in use the plant for making the various forms of gaseous fuel which are required for heating and lighting purposes, requires to keep abreast of chemical progress in these departments, and he will be seriously handicapped if he endeavours to proceed unaided and unadvised by the chemist, and if his products are not frequently subjected to chemical examination.

Waterworks and Water-Supply.—The design and construction of waterworks is pre-eminently an engineering undertaking, and includes not only the provision of suitable borings, conduits, storage reservoirs, and pumping stations, but also of suitable and satisfactory filter beds when necessary. But here, again, if the health and requirements of the consumers of the water-supply are to be properly considered, the chemist must determine the

character of the water source from which the supply is to be derived. He must ascertain its relative purity during the different seasons, its behaviour in contact with leaden cisterns and service pipes, and the means of preventing any risk of the water becoming poisonous from contact with lead if the supply is soft, or of diminishing or preventing the waste of soap and the formation of boiler scale if the water is hard. He is also charged with the duty of constantly examining the water as it is supplied to consumers, in order to ascertain whether filtration is properly and efficiently carried out, whether the bacteria condition of the supply is satisfactory, and to make sure that the water does not receive any constant or casual pollution on its way to the consumer. Hence, in the matter of water-supply, both the engineer and the chemist find their respective but closely connected spheres of duty.

Sewage Treatment and Purification.—There is another direction in which the constant relation of chemistry to engineering and the association of the chemist with the engineer must be maintained, if success is to be secured and expensive failures are to be avoided.

Neither the engineer nor the chemist, alone and unaided, is the proper person to deal with the disposal of the sewage of our towns. In the final stage of designing and constructing and maintaining the necessary works on the large scale, as well as in the construction of works on the earlier experimental scale, the engineer undoubtedly finds his necessary and natural sphere. But it must be remembered that the processes by which the purification of town sewage has been accomplished, and has been from time to time improved, have invariably been evolved, directly or indirectly, by the chemist, and depend on chemical investigation, checked by the results of chemical analysis. It should further be borne in mind that, when any process of treatment has been established on the large scale, the results of its working, as in the parallel cases of gasworks and waterworks, must be constantly checked by chemical examination of the products.

It is not sufficient to pronounce a sewage effluent to be satisfactory because it is clear and inoffensive as it issues from the purification works. When the sewage has been clarified, something has been accomplished, it is true, and due credit should be given for the improvement. But it is often only necessary to subject such a clarified effluent to examination by ordinary processes of chemical analysis in order to learn that it is laden

with dissolved impurities, which are at the moment invisible to the eye and inappreciable to the sense of smell. When this effluent is exposed for a short time to natural summer temperatures, or to artificial summer heat in the chemist's laboratory, it runs rapidly into foul putridity.

Such an effluent should manifestly not be looked upon as having undergone successful treatment, and should not be admitted into any ordinary watercourse. It will certainly deprive any stream, into which it is discharged, of its vital dissolved oxygen, and will therefore render fish-life impossible. It will probably, either constantly or occasionally, cause the stream itself to become foul, since, in the absence of dissolved oxygen, these dissolved impurities rapidly undergo putrid changes. The mere examination of such an effluent by the ordinary senses will evidently be entirely misleading, and it is only by the chemical examination of the effluent that its true character will be made known. The frequently-repeated chemical examination of effluents is necessary in order to ascertain that their condition is such as will not lead to the creation of nuisance or offence.

The tendency of those in charge of any process of sewage treatment, if they proceed without frequent information from and consultation with the chemist, is to be satisfied with an effluent which is apparently, but not really, of a satisfactory character. When the clear but impure effluent leads to nuisance, the temptation is to proceed to the erection of large and costly plant either for the improvement of the existing process or for the application of some newer method of treatment. This expenditure may be undertaken before the additional plant or the newer method has been tried on a small scale and thoroughly tested under the supervision of the chemist. The expenditure thus incurred may accordingly lead to no good result, and the new venture may prove to be a failure as far as good results of purification are concerned.

In the development on the large scale of a scheme of sewage treatment, which shall be suitable for any particular centre, the engineer finds one of his most valued and important spheres, but he should undoubtedly associate himself with a chemical adviser in the early experimental stage of testing the suitability of the process; and after the scheme is in operation on the large scale he should secure the advantage of the co-operation of the chemist in constantly examining the true character of the effluent which is being produced, and in ascertaining its effect upon the watercourse into which it is being discharged.

In no application of chemical and engineering principles is the co-operation of chemist and engineer more necessary for the attainment of success than in securing the suitable purification of our town sewage. Such co-operation has enabled London, Manchester, and other large centres of population in recent years to carry out on an experimental scale most important trials of the natural or bacterial treatment of sewage, and has led to reports on this method being published which will probably become classical. This experimental work has led to considerable and valuable development and improvement of the bacterial method. There is now no doubt that this process can inexpensively dispose of a large proportion of the putrescible sediment or sewage-sludge, and can render the effluent not only non-putrescible and suitable for maintaining the life of fish, but even pure if necessary. The process is therefore destined to effect great reforms in our sewage-disposal problem and considerable improvements in the condition of our watercourses.

It should be understood that the purification thus effected is in the true sense of the term "natural." It is brought about by the extremely minute vegetable organisms, known as bacteria, which are present in vast numbers in the sewage itself. The bacteria present in the sewage only require to be placed under suitable conditions in order to exert their extraordinary purifying influence. It is, therefore, by agencies naturally present in the sewage that it is rendered inoffensive, or even, if necessary, pure. No extraneous artificial substance is added. The direction in which recent improvements are tending for effecting our sewage purification are in the direction of simplification, and are effected by allowing natural processes to have their freest and fullest play, instead of applying artificial mixtures of chemicals.

If the engineer co-operates with the chemist and physiologist by first appreciating and grasping these recent facts of natural treatment and then devising and adapting suitable plant for applying them on the large scale to our town sewage, he will be fulfilling his true function and will be applying the forces of Nature to the advantage of mankind. Manchester at present leads the van in this important movement, since it is constructing bacteria tanks and beds on the large scale; London, Leeds, and many other centres are feeling their way; and the speed with which the system is generally adopted will naturally be largely affected by the interest taken by our sanitary authorities in adopting the best methods of sewage purification.

By the long and patient experimental investigation of this

natural process of treatment results have now been obtained which admit of extended application, and the time has arrived when chemist and engineer may advantageously co-operate in carrying out natural schemes of sewage purification on larger and larger scales.

Detection and Estimation of Inflammable Gas and Vapour in Air.

Reference may be made in conclusion to one more instance in which the engineer has rendered it possible for chemical experiments to receive a useful and wide application, and in mentioning this illustration I am glad to have the opportunity of making acknowledgment before an association of engineers of the advantage which I have personally derived from the co-operation of engineering friends.

Much of my life has been spent in the Midlands and in the immediate neighbourhood of large collieries. As a chemist I naturally felt much interest in the application of the safety-lamp of our great English chemist, Sir Humphry Davy, to the purposes of lighting and gas-testing in our coal-mines. Living, as I did, near the collieries, I had facilities for learning the experience of those who constantly used this lamp, and was also able to make my own observations and experiments on the lamp both in its original and in its improved forms.

What especially interested me was the application of this lamp to the detection of inflammable gas or fire-damp in the air of the mine. The gas was originally and is still detected by its power of causing a conical pale flame to appear over the reduced and almost non-luminous flame of the lamp. This is known as the "flame-cap" indication of gas. It was observed and regularly utilized even before safety-lamps were employed for lighting the pits. The candlewick was cut short, and the direct light of the small flame was screened from the eye by the hand when the pale flame-cap was being looked for.

It has always appeared to me that this, the original method employed in the coal-mine for detecting gas, was a more ready and practical means than any of those which depend upon other principles. I have long wished to improve this test and to make it more delicate and practical. I wished especially to render it available for measuring the percentage of gas present in the air in order to learn how near the mixture is to its flaming or exploding point.

Experiments directed towards this object showed that the flame

of burning hydrogen-gas was peculiarly suitable, on account of its non-luminous character and its very high temperature, for producing large and visible flame-caps. And it was found possible to introduce such a flame into an ordinary safety-lamp, and to use it alternatively with the oil-flame. This was effected by attaching a small light cylinder of compressed hydrogen to the lamp. The oil-flame could then be employed in the lamp in the ordinary way for illuminating purposes, and the hydrogen-flame could be substituted for the oil-flame in a few seconds without opening the lamp, and could be employed for testing for gas by the flame-cap method.

It was found possible not only to detect as small a proportion of firedamp as 0·25 per cent. in the air by this means, but also to measure the percentage of gas present until it reached the explosive proportion. The measurement was secured by setting the hydrogen-flame to a standard height and then noting the height of the flame-cap by means of a properly constructed scale fixed inside the lamp.

Incidentally it was found that the hydrogen-flame could with advantage be burnt within the lamp in order to prevent loss of the flame in passing through parts of the mine containing atmospheres which would extinguish the oil-flame. The hydrogen-flame requires but little oxygen to maintain its combustion, and therefore remains burning under such circumstances, and rekindles the extinguished oil-wick as soon as a better atmosphere is reached. The hydrogen-flame was also found to resist, far more successfully than the oil-flame can do, extinction by sudden shock or mechanical means. This combined oil- and hydrogen-lamp has proved itself of use to mining engineers.

In the early stage of this experimental work Dr. Boverton Redwood approached me with the idea of applying the hydrogen flame-cap test to the detection and measurement of petroleum vapour in the air. This is of extreme importance in connection with the examination of the air within the empty tanks of our petroleum-importing steamers when the tanks require to undergo repair by engineers. By designing a suitable form of apparatus, the process of testing by means of the hydrogen flame was made perfectly satisfactory, and it has now displaced the methods which were formerly in use for detecting petroleum vapour. The air to be tested is pumped out of the interior of the empty petroleum tank, and is made to pass over a standard hydrogen flame provided with a suitable scale, and similar to that used in the miner's safety-lamp. Dr. Redwood described the apparatus to

this Institution in a Paper on "The Transport of Petroleum in Bulk."[1]

Another form of portable apparatus was devised, by means of which air could be drawn from any neighbouring space, and could then be tested for combustible gas or vapour upon the spot. It was applied, for example, to the detection and measurement of coal-gas, which had leaked into the conduits of street electric mains, and it has been used with advantage by gas engineers.

I may say at once that while a long series of laboratory experiments and measurements were necessary, in order to establish the practicability of this method of detecting and measuring inflammable gas and vapour in air, the perfecting of the apparatus in a practical form was due to the very ingenious suggestions made by friendly members of the firms of Messrs. Manlove and Alliott, of Nottingham, and Messrs. W. J. Fraser & Co., of London. Without the co-operation of these gentlemen I cannot but feel that my own labours would have lacked their final success. All the above forms of testing-apparatus are described in a book on "The Detection of Inflammable Gas and Vapour," published by Messrs. Crosby Lockwood and Son.

Conclusion.

In concluding this address, I feel that I have only been able to touch in barest outline upon what is really a very large and important subject, and one in which the public welfare is deeply concerned. It is true that as knowledge advances, it becomes increasingly difficult for the engineer or the chemist to learn much of any department of knowledge except that which most nearly concerns him. But this fact renders it the more necessary, in the interest of progress and success, that the members of these two important professions should heartily co-operate, and should place at each other's disposal the knowledge and advice which each may be able to offer. Such co-operation of the engineer with those who have specially devoted themselves to the various natural sciences will help this country to maintain that glorious prestige amongst the nations which the noble labours of a long succession of great engineers have conferred upon it.

The Chairman, in proposing a vote of thanks to Dr. Clowes, remarked that the lecture, which was not less interesting and

[1] Minutes of Proceedings Inst. C.E., vol. cxvi. p. 177.

instructive than any which had preceded it, had proved very fully that engineers might be much assisted in their work by co-operation with the chemists. He had had 40 years' experience as a waterworks engineer, and from the very beginning he had been associated with many analysts, particularly Dr. (afterwards Sir) Edward Frankland, with whom, he was glad to hear, Dr. Clowes had been associated in his early student days. Some 35 years ago he remembered having to report with his partner on a sewerage scheme for the towns in the island of Malta, and a question had arisen as to the use of sea-water for flushing. It had been intended to use the sewage for the irrigation of land, and they had not been quite clear whether the introduction of salt water for flushing would be detrimental or not. He had therefore paid a visit to Dr. Frankland, who had been his tutor some 15 years previously, at Queenwood College in Hampshire, where, he had learned that evening, Dr. Clowes had ultimately succeeded him. Dr. Frankland had told him that he would not be able to deal with sewage without the assistance of a chemist. At that time Dr. Frankland had not had much experience of sewage disposal; but very soon afterwards he had been appointed a member of the Rivers Pollution Commission, and it had been very striking to find how his investigations seemed to alter his original views. As was well known to many present, Dr. Frankland had been the writer of the greater part of the second report of the Commission which had resulted in a strong and emphatic recommendation of land irrigation as the best means of dealing with sewage. Dr. Frankland had been unable to resist the evidence which he and his colleagues had taken, showing that land was the most effective means, and for a time treatment with chemical agents had been set aside; but, owing to the cost of obtaining a sufficient area of land suitably located in respect of levels, he had ultimately devised the method of intermittent downward filtration, which was an intensified form of irrigation requiring a much smaller area. Great progress had been made in the treatment of sewage of late years. The lecturer had referred to the bacterial process, which was now very much to the front, and which would no doubt be exceedingly useful in the treatment of sewage in many positions. Unfortunately, however, the cost of constructing the tanks, and filling them with suitable material, was so great, that in some situations land might be found to be the cheaper method of the two. That, however, remained to be seen. There was no doubt that the use of the septic-tank process, in reducing the trouble and cost of dealing with the sludge, was an enormous gain. He had great

pleasure in proposing a hearty vote of thanks to Dr. Clowes for his lecture.

Sir WILLIAM PREECE, K.C.B., Past-President, in seconding the resolution, remarked that while the lecturer had told them a good deal of the association between chemists and chemistry and engineers, he had also shown them one thing which engineers missed very much in their discussions and addresses, namely, knowledge of the elements of pure language and clearness of articulation and speech. Every branch of engineering would learn a good deal from the lecture, which all would read with great pleasure.

Dr. CLOWES, in reply, expressed his appreciation of the way in which the members had received his lecture, and acknowledged the kindly terms in which the President had proposed the vote of thanks. When he had received the very complimentary invitation of the Council of the Institution to deliver the lecture, one of the inducements to comply with their wish had been to see the name of the seconder of the proposal as the previous lecturer, and a series of illustrious names as his predecessors. It had been a great pleasure to him to have the opportunity of speaking to such an audience, and, above all, to learn that they appreciated his efforts.

The preceding lectures of this series have been :—

Date.	Subject.	Author.	Proceedings Inst. C.E. Volume.
1893	"The Interdependence of Abstract Science and Engineering"	Wm. Anderson, D.C.L., F.R.S.	cxiv.
1894	"Relation of Mathematics to Engineering"	John Hopkinson, D.Sc., F.R.S.	cxviii.
1895	"The Development of the Experimental Study of Heat-Engines"	Prof. W. C. Unwin, B.Sc., F.R.S.	cxxii.
1896	"Physical Experiment in Relation to Engineering"	Alex. B. W. Kennedy, LL.D., F.R.S.	cxxvi.
1897	"Bacteriology"	G. Sims Woodhead, M.D.	cxxx.
1898	"The Relation of Geology to Engineering"	Prof. W. Boyd Dawkins, M.A., F.R.S.	cxxxiv.
1899	"Magnetism"	Prof. J. A. Ewing, M.A., B.Sc., F.R.S.	cxxxviii.
1900	"The Relations between Electricity and Engineering"	Sir William H. Preece, K.C.B., F.R.S.	cxlii.

Sect. II.—OTHER SELECTED PAPERS.

(Paper No. 3242.)

"The Location and Construction of Railway Tunnels, with Particulars of some recent Work."

By Arthur Edward Rogers, M.A., Assoc. M. Inst. C.E.

Owing to the great increase, in recent years, in the demand for rapid transit, it has frequently become necessary to provide lines of railway to connect important centres of population in the most direct manner possible. This has, in many instances, rendered unavoidable the construction of tunnels through intervening ranges of hills; for, however much mechanical means of excavation may have reduced the cost of heavy cuttings and embankments, there must be a limit of depth beyond which a tunnel becomes a necessity. The increasing demand for easy gradients and curves of large radius compels the engineer, in designing a new railway, to make most careful calculations of the relative cost of alternative routes, wherever such differences of elevation exist as to render tunnelling a possible solution of the difficulty. In considering this question it may be necessary to take into account contingent causes of expense which may be obviated by a tunnel, such, for instance, as the danger from insecure ground, in which slips of great magnitude, and entailing enormous expense and delay in traffic, may occur, even many years after the opening of a railroad; or, where cuttings are liable to be blocked by snowdrifts or avalanches, a tunnel may be regarded in the light of a permanent and satisfactory form of snowshed; again, in thickly-populated districts or in towns, owing to the great cost of land, it may be imperative to conduct the railway in tunnel. This is at the present time a very important cause of tunnel construction in England, where the introduction of electric traction has rendered it possible to provide low-level means of communication in great towns, a convenience formerly much interfered with by the impossibility of providing such ventilation as the use of steam locomotives rendered indispensable.

In arriving at an estimate of the cost of a tunnel, it is necessary to consider not only the length of the proposed work and the

depth of the shafts, but also the nature and disposition of the various strata and formations through which the tunnel will pass. The accurate geological surveys, which now exist in the case of most civilized and thickly-populated countries, greatly facilitate the task of arriving at an approximate knowledge of the nature of the ground, and it is generally possible to ascertain from them the actual formations to be met with, and the general dip of the strata. The greatest difficulties in tunnelling, however, are generally caused by minor faults, or pockets of sand or water, the existence of which no geologist can ascertain except by actual experiment. In the construction of the tunnel south of Sevenoaks Station, on the South-Eastern Railway, when the headings penetrated through the Wealden clay, which dips in a northerly direction, it was found that the Lower Greensand above was so saturated with water that the contractors were unable to deal with it, and the work had to be completed at great cost by the Railway Company. It was at first thought, even by geological experts, that this was merely a pocket in the clay, full of water; but it has since been proved by the unfailing supply pumped from a well close by the side of the tunnel, into which the water is led, and which forms the water-supply of Sevenoaks and the neighbourhood, that a much greater area of percolation must have been tapped than was at first supposed, including probably the slopes of both the Mid Kent Range and the North Downs, the Lower Greensand forming, in fact, a reservoir confined between the Wealden and Gault clays.

In the Kilsby[1] tunnel, on the London and North Western Railway, the greatest difficulty was experienced in making way through an extensive pocket of running sand, the existence of which had not been at all expected, as trial shafts, sunk to ascertain the character of the material, had unfortunately not touched it, and had only revealed sound ground. Both these cases show the urgent necessity of ascertaining, when possible, by means of frequent shaft-sinkings and borings, what may be the real character of the ground in the actual line of the tunnel. Shafts are by far the most instructive, as they enable the amount of water and the pressure exerted by the various materials to be ascertained, and it is then possible to estimate approximately the provision which must be made for drainage, and the thickness of lining required. As they can be afterwards used

[1] See "The Life of Robert Stephenson, F.R.S.," by J. C. Jeaffreson; London, 864, vol. i. p. 200.

for the construction of the tunnel, some compensation is obtained for the difference in the cost. In some cases a heading has even been run before the main contract has been let, in which case there should be no difficulty over extra expenses in the final account. This procedure is, however, not advisable except in very sound formations; a bottom heading, especially, should be avoided in clay. In one of the low-level tunnels under London, frequent borings revealed the existence of a depression in the London clay, which would have brought the overlying water-bearing gravel into the line of the workings. Owing to this discovery the levels were altered and the tunnel was taken down into the solid clay, thus avoiding the gravel pocket which might have caused much trouble.

The easiest material through which to tunnel is a sound sandstone, hard enough not to require lining, and yet easily excavated. The most difficult and dangerous is probably a running sand, which is fortunately not often met with except under river-beds, where it is generally necessary to work in compressed air. On the Glasgow Central Railway the tunnel met sand, and, in spite of a drainage heading underneath, this caused great difficulty, the sand running so fine that it would come through a straw. Quartzite and other very hard primary and igneous rocks are very difficult to tunnel through, but are safe to work in, and require no lining. The invention of rapid-acting drills and high explosives has made it possible to tunnel through rock of any degree of hardness, but it has proved a very slow and tedious process to make a way through the dykes of quartz which have been met with in the Simplon tunnel, even with the most modern methods and appliances. Sometimes rock which is both hard and unsafe is met with. In the tunnel now under construction at Ampthill, a considerable length is through a very hard rock lying against the face of the excavation, the joints dividing the material into wedges with the thin end upwards, thus throwing all the weight on the bars.

When the general line and level of any tunnel has been decided upon, it may be possible to considerably facilitate the work by comparatively small deviations. Thus it may occur that the formation consists of varying strata, some thick and of a sound material, others thin and much saturated with water. In such a case, if the dip of the strata be steep, a deviation to the side may put the tunnel in the sound stratum when the original line cuts the water-bearing stratum, and the same result may be obtained where the strata lie horizontally by a small deviation in the levels. In English practice it is generally

impossible to avoid bad ground, owing to the difficulties of altering the line or level, but in wild countries these points should receive careful consideration.

In crossing a watershed or line of hills by a tunnel lying under a dip in the crest-line, as will often occur if the railway runs up a valley on one side of the watershed to meet a valley on the other side, it is necessary to ascertain the cause of the dip. This may have been eroded in consequence of a fault, in which case the tunnel should be located to one side or the other of the fault, which will have caused crushing of the rock, and will probably be saturated with water. Or it may be the result of the detrition of the loose and broken rock in the top layers of an anticlinal fold which may lie below the dip, and may introduce much lower strata of quite a different character into the line of the tunnel. In the case of a mountain slope, if the dip of the strata is parallel to that of the upper surface there may be a danger of sliding caused by any disturbance of the beds, especially if the comparatively softer character of some of them may have caused depressions in their outcrop, which, acting as catchment basins for the drainage of the upper slopes, keep the soft material below in a saturated state, and so increase the tendency of the harder layers outside to slide. One of the cuttings on the Midland Railway, in sidelong ground, gave a great deal of trouble during construction owing to the hillside above evincing a strong inclination to slide into the cutting. Where the strata dip at right angles to the mountain slope, or lie horizontally, there is less danger of trouble from this cause. Care should always be taken to avoid, if possible, the location of a tunnel in any position towards which the lie of the strata naturally tends to conduct water; this is, in all cases, whether of open cuttings or tunnels, the cause of the greatest difficulties. The exact length of any tunnel can seldom be fixed, as the position of the faces must depend on the character of the ground as found by trial, and it may be necessary to extend by cut and cover where the foundation at the point originally selected may not be considered sufficiently sound to carry the surcharged slope.

The first proceeding in the construction of a tunnel is generally the sinking of as many shafts as may be found necessary and practicable, having regard to the time of completion and the cost. It is seldom possible to commence work immediately at either of the tunnel faces, as these are generally, except in mountains, situated in deep cuttings which must be previously excavated. From each shaft driving is then begun in both directions. In

most cases, where the slopes of the hill are not very steep, it is possible to dispose of the material excavated from the mouth of each shaft, and no connected heading is therefore driven. But in some instances, owing either to the great depth of the shafts, or the impossibility of obtaining land on which to deposit the spoil or lay the route, it becomes necessary to drive a heading right through the tunnel by which wagons may carry the spoil to bank at either end. In this case the number of shafts is limited, and extra working faces are obtained by means of break-ups from the bottom heading.

In the Ampthill[1] new tunnel, the shafts being between 200 feet and 300 feet in depth, and there being no possibility of getting a route for wagons over the top, the work has been carried on from six shafts and two break-ups, making sixteen working faces, and the bottom heading has been driven from end to end. In the short tunnel forming the extension of the Liverpool Overhead Railway to the Dingle this method had also to be resorted to, a bottom heading being driven from five shafts, and twelve break-ups being then made.

In the Catesby[2] tunnel, having a total length of 3,000 yards, there were nine shafts, and a bottom heading was driven from a point in the cutting, 3 chains north of the north face, to meet the work, in consequence of the difficulty of access to the land above. This heading caused trouble, as it was unfortunately in the heaviest ground met with, and the timbering had to be of exceptional strength. This tunnel is all in the Lower Lias, the heavy work of the northern end being in the Capricornus, and the remainder in the lower Margaritatus zone. The shafts are all 10 feet in diameter inside, except the most northerly of the permanent shafts, which is 15 feet in diameter and is situated $\frac{3}{4}$ mile from the north face. Shafts which are to be permanent generally require lining except in very solid and dry rock, while temporary shafts are left timbered until the completion of the tunnel, and are then carefully filled in. The permanent shafts at Catesby were lined with five rings of brickwork. Water is more likely to be met with in the shafts than in the tunnel, owing to the larger number of beds which, if the strata lie approximately horizontal, must be cut through. In permanent shafts where strata containing much water are found, which would, if left simply faced with brickwork and unprovided with any special

[1] Minutes of Proceedings Inst. C.E., vol. cxx. p. 335.
[2] *Ibid*, vol. cxlii. p. 37.

arrangement, cause a drip from the shaft into the tunnel, some method of drainage similar to that used in the Catesby tunnel may be employed. In this case an annular brick chamber was built round the shaft lining at the level of the water-bearing bed, and the ground was made tight below it. From this collecting-chamber pipes were led inside the brickwork of the shaft and of the arch and side-wall below, to the central tunnel drain. This high-level supply was in one case afterwards used to supply by gravitation the station at the south or upper end of the tunnel.

There are several systems of construction of the actual tunnel, of which the English system is the one most in use in this country, as it has proved more economical in timber, more rapid, and safer in any soft material than the others. In this system the excavation is first got out for the top heading, which is kept somewhat in advance of the rest of the face and in which the crown-bars, 18 inches in diameter, or larger according to the weight to be supported, are set; the heading is then widened until the whole of the upper timbers required are in place to the level of the top sill. The excavation is then carried down to the level of the lower sill, on which the top sill is supported by under-pinning props. Rakers are also placed to stiffen the sills against the face of the excavation, which is boarded. The excavation is then completed to the required depth. This operation is performed in lengths varying according to the ground met with, but generally of 12 feet or 15 feet, though occasionally lengths as short as 10 feet or as long as 18 feet are worked, in exceptional cases. In this manner the whole section of the tunnel is left free for the bricklaying gang, who now follow, erecting the centering, and completing the lining behind. Where there is an invert, the bricklayers lay it first, and then the side-walls. They remove the timbering as the walls rise, but in bad ground it is sometimes necessary to leave the poling-boards in. When the lowest of the six drawing-bars is reached, the space below it, outside the arch, is bricked in tight. As the arch rises, 9-inch walls are built between the extrados and the poling-boards to support the latter when the bars are drawn forward for the next length. Another length is then excavated and the six highest and largest bars are drawn forward as this proceeds, their ends resting on the finished arch behind and on the props put in to receive them in front. The spaces left by them between the 9-inch walls are then carefully packed with dry material to prevent any more settlement of the ground above than is unavoidable. Care must especially in shaft lengths, that the brickwork be well bonded. The height at which the crown-bars are set

above the finished work must be decided from experience in dealing with the material. In the heavy ground at Catesby the bars came down as much as 2 feet in some cases, and if they are not set sufficiently high to allow of this movement it may be necessary to shave them in order to get in the full thickness of the arch, in which case the bars have to be left in.

In the Belgian system the arch-ring is built after only the upper portion of the core has been removed. This is then underpinned and the central core is taken out.

In the German system the side-walls are first built in two headings. The upper part of the core is then removed and the arch is put in, after which the centre is cleared.

In America,[1] owing to the cheapness of lumber, it has been customary to timber the whole tunnel, and in some cases timber has been used as the actual lining for the tunnel.

It has been the general practice in England to build the "side-lengths" at the foot of a shaft before putting in the "shaft-length," and thus to support the bars for the latter on the completed arch on either side. In the Catesby tunnel, however, the shaft-lengths were built direct, the two bars which actually came into the footing of the shaft being left in, and the others being drawn in the usual way. This has also been done in the Ampthill tunnel now in course of construction by the same contractors.

Where two sections meet, the top heading is driven through for a distance of 1 chain to 2 chains, for the purpose of correcting any error in alignment which may have occurred. Care must be taken, where two sections of the completed tunnel meet, in regard to the final keying-in, which must be done on draw-laggings set transversely in rabbets, the final "pigeon-hole" being keyed from below. The use of cement in building the arch, especially in wet lengths, strengthens all points such as this, and enables the centering to be struck much sooner than with lime work, thus reducing the amount of timber required. The section and thickness of the brickwork depend on the nature of the material. In loose rock not exerting any great pressure, as in the Liverpool Overhead Railway tunnel, three rings have been sufficient for both walls and arch. At Catesby, the normal section consisted of five rings in the arch and side-walls and four rings in the invert; but at the north end, where the ground was heavy and the work complicated by the necessity of

[1] See "Tunnelling, Explosive Compounds, and Rock Drills," by Henry S. Drinker; New York, 1893.

having a bottom heading, the thickness had to be increased to seven rings in the arch, and six rings in the invert, and for one or two lengths even to eight rings. This was necessitated by the difficulty in keeping the heading open and by a settlement which started above the tunnel. A small length of this tunnel at the north end was in cut-and-cover, and an interesting question arose as to the cost of this method in very shallow ground as compared with that of tunnelling, one length of tunnel executed being so little buried that the crown-bars were laid in trenches cut down from the surface.

In the Mersey tunnel[1] two independent headings were driven, for drainage and for ventilation. The drainage heading conveys the water which percolates into the tunnel in large quantities, to sumps on each shore, from which it is then pumped. This was finished in advance in order to drain the works while in progress. The ventilation loop-heading takes the foul air from various points, principally the centre of the tunnel, to powerful fans on either bank, thus causing a draught of fresh air into the tunnel from each of the low-level stations.

The Simplon tunnel[2] now under construction is a double tunnel with connecting passages. This has proved to be the most economical and rapid method of construction, the tunnels being carried on alternately and the workmen in either advancing heading retiring into the other tunnel to avoid the effects of the blasts.

Where water is found in the excavation it is possible, if the ground be sound and not liable to wash out behind the brickwork, to conduct it, by chases cut in the brickwork or channels in the rock, round the extrados and down the back of the side-walls to pipes leading through into the main tunnel drain. At Catesby, the tunnel drain, which is 4 square feet in cross-sectional area, is laid in the centre of the invert, with an arched crown, and is provided with catchpits, 5 chains apart, throughout its length. The question of the best gradients to be adopted in a tunnel seems to be a disputed one. The general practice in a summit tunnel has been to make the summit of the tunnel in the centre, as some gradient must be allowed for drainage. In the Catesby tunnel the gradient is continuous throughout, falling 1 in 176 from south to north. It is said that this provides an advantage in assisting ventilation, as the draught blows

[1] Minutes of Proceedings Inst. C.E., vol. lxxxvi. p. 40.

[2] *Ibid*, vol. cxl. p. 249.

naturally through the tunnel in consequence of the greater speed of the trains on the descending line. These shut off steam and create a minimum of foul air, while the steam and gas from the ascending engines is blown back and does not follow the train up the tunnel. It is doubtful, however, whether the air does not really merely eddy in the rear of the descending train and not draw from end to end. The Catesby tunnel keeps clearest when the wind blows from the north up the tunnel; but the north face is much more exposed than the other. In some tunnels, especially among the mountains on the Continent, where the draught sets continually up the steep gradient, the air which travels with the ascending train has become so foul that the fires have been almost extinguished and the engine-men have fainted on the footplate. In these cases it has been necessary to erect various contrivances to force the draught down the tunnel, and the Saccardo system, which not only forces in a large volume of air, but also causes an induced draught on the principle of the injector, has proved the best of the remedies applied. This system is only permissible where no intermediate stations exist, and cannot therefore be applied to city tunnels. Owing to the difficulty and danger of plate-laying in tunnel, it is important that the permanent way should be of the best quality. In some cases sleepers of larger size have been used. On the Liverpool Overhead Railway these are 12 inches by 6 inches in cross section. The ballast also should be of the cleanest and most easily packed description. For the same reason the lining should be as sound as possible. Staffordshire brindle bricks were used throughout at Catesby. For the safety of the men refuges must be built at intervals, and, if the tunnel is of considerable length, a large recess to act as a mess-room and tool-house for the men is an advantage. There were three such recesses provided at Catesby.

The provision of low-level means of communication in great towns has led to a method of construction entirely different from the foregoing. This method was first used systematically in England by the late Mr. Greathead on the City and South London Railway. A cylindrical shield of the requisite cross-section is used, having in front a cutting edge. This is placed in position in the bottom of the shaft or in a chamber constructed on the line of the tunnel, and is impelled forward by hydraulic rams, the core being excavated as the shield proceeds. Inside the rear portion of the shield, which consists only of thin plating, are bolted together cast-iron segments forming the lining of the tunnel

and the very small space left by the tail of the shield round the cast-iron cylinder is then filled with cement or lime grout under pressure. By this method all disturbance of the upper surface is obviated, and it is possible to tunnel under buildings without doing any damage. Should the face be soft enough to come forward, the shield is divided into compartments, only one of which is taken out at once. From the time of Sir Isambard Brunel and the Thames Tunnel, various forms of shield have been tried, especially in America; but previous to Mr. Greathead's undertaking no great advance was made. The tunnels in this case were 10 feet 2 inches to 10 feet 6 inches in diameter, and the greater part of the line was more or less subaqueous. Where the material was so wet as to require it, the work was done in compressed air. The construction of this work and the methods adopted for overcoming the water-pressure, etc., are described in a Paper[1] by the late Mr. J. H. Greathead, read before the Institution in 1895. Owing to the remarkable absence of disturbance caused by the shield-driven cast-iron tunnel, this system is now being largely used in similar deep-level tunnels, even where no water is to be met with.

In the Great Northern and City Railway, when the face has progressed far enough, the lower half of the cylinder is replaced by brickwork, and the cast-iron segments are used for the roof further on. One of the difficulties which appeal to the engineer in the construction of these town tunnels is the great accuracy required in the setting-out. Owing to the value of building property the line has to be so arranged as to lie under the roads, and it is therefore impossible to get sites for shafts on the actual line of the tunnel. On the Great Northern and City Railway the main working shaft is nearly 100 yards from the tunnel, and a subway has been driven under a canal to the chamber in which the four 16-foot shields were erected. The transferring of the line to the shaft and then back along the subway has required the most minute care, and every ring of the cast-iron lining has been checked as soon as erected, to prevent any possible error in line or level. The introduction of lifts of large capacity and great speed has brought this low-level work comparatively near the surface. Great trouble was experienced with the earlier shields in preserving the cylindrical form and in the prevention of a tendency to drop or tip forward as the shield advanced. This is now carefully checked by the rams, which are turned on as required so that

utes of Proceedings Inst. C.E., vol. cxxiii. p. 39.

any part of the cutting edge can be made to lead. In the Great Northern and City Railway, the shields, 16 feet in diameter, are each provided with sixteen rams, 7 inches in diameter, designed to work at a maximum pressure of 2 tons per square inch. The average working pressure in the London clay is 17 cwt. to 19 cwt. per square inch, rising at the end of the stroke according to the quantity and density of the material left by the excavators for the cutting edge of the shield to pare off. These rams were worked at first by compressed-air engines, but these were found to freeze the water and were abandoned, the pressure being now brought down the shaft from the surface.

In the Blackwall[1] tunnel, 25 feet in internal diameter and 27 feet 9 inches in external diameter, twenty-four 7-inch rams were at first used and four 10-inch rams were afterwards added. The pressure was about 3 tons per square inch when driving through water-bearing ballast, when the area of the shutters was about one-half that of the whole face of the shield. One of the important advantages of this system over the older one is in the speed of construction. Whereas a double line brick tunnel progresses at the rate of about 1 foot per face per day, the 16-foot tunnels on the Great Northern and City Railway have proceeded at an average rate of five rings or 8 feet 4 inches per face per day, and the 21-foot station tunnels at the rate of four rings or 6 feet per face per day. The Central London Railway tunnels maintained an average rate of 6 inches per hour. Thus it may be considered that, except in certain cases of cut-and-cover, the day of brick tunnelling in underground town railways is past.

For some of the particulars given in this Paper the Author is indebted to members of the staffs of the engineers or contractors engaged in carrying out the several works mentioned.

[1] Minutes of Proceedings Inst. C.E., vol. cxxx. p. 50.

(*Paper No. 3283.*)

"On Some Applications of Transition Curves."

By GABRIEL JAMES MORRISON, M. Inst. C.E.

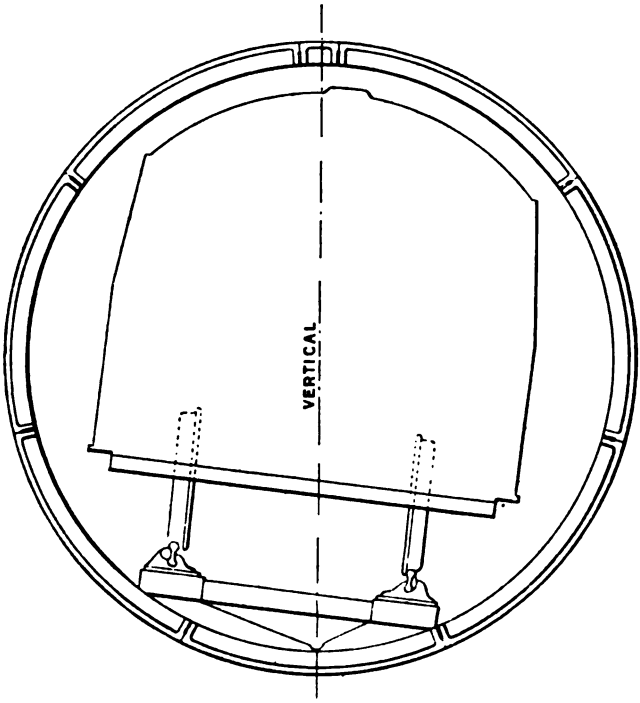
THE subject of Transition Curves was carefully investigated by Mr. Froude more than 50 years ago, but their employment has been looked upon as a mathematical refinement, and their introduction in practical setting out may be safely said to be the exception and not the rule; yet there have been laid thousands of miles of railway, along which trains travel at the highest speeds, without any apparent inconvenience arising from the omission of transition curves. The platelayer in practice eases off the junction of the straight line and the curve at the expense of increasing the curvature at another place, and in the face of the experience of half a century it would be absurd to say that this rule-of-thumb method is fraught with danger.

In recent years, however, the construction of underground railways, on which carriages propelled by electricity are run through circular tubes which they practically completely fill, has introduced an entirely new element which appears to have escaped general notice, the tubes being, as a rule, set out with circular curves tangential to the straight lines. In a tube-railway, as elsewhere, a certain amount of superelevation must be given to the outer rail on curves, but as the carriage nearly fills the tube this can only be done by moving the permanent way to one side, following the curve of the tube (*Fig. 1*), and in this way the amount of superelevation and the position of the line become connected in a very curious and embarrassing manner. It is true that on quick curves the size of the tube is sometimes increased, but this is required to give clearance for the ends of the carriages at the outside and for the middle of the carriages at the inside of the curves. There is no clearance available for superelevation.

Let the tube be laid with a circular curve tangential to a straight, and, as a first attempt, let the centre line of the permanent way be laid out in the centre of the tube on the straight, and to one

side in the curve, in order to give superelevation; the result will then be as shown in *Fig. 2.* Easing off the junction, or rather want

Fig. 1.



Scale, ½ inch = 1 foot.

of junction, of the straight line with the curve is here a much more serious matter than in the open. The straight line may be continued forward and gradually made to join the curve, but this means

Fig. 2.



entering a curve, and possibly a very quick curve, without any superelevation, and will be bad, although it may satisfy the eye. Probably the best method is to lay the rails in the manner

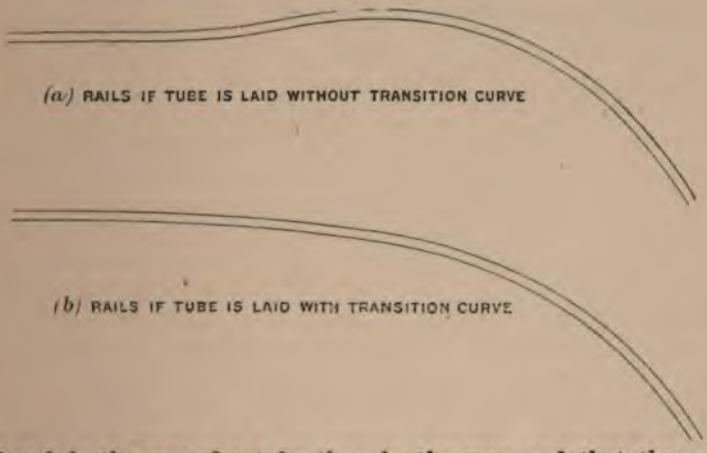
indicated in *Fig. 3 (a)*. In the open such a line would be unobjectionable, and would, as a matter of fact, be much better than the platelayers' rule-of-thumb line, since the proper amount of superelevation could be given at each point. In the tube, however, quite another state of affairs exists. Superelevation is no longer independent of line, but is absolutely dependent upon it, and where the line gradually moves to the left the inner rail of the curve is higher than the outer. It is true this curve may be made very flat, but the flatter it is the further on will be its connection with the circle, and the further it will be moved from the centre of the tube, so that at the point of change of curvature, where there may be a piece of straight, and where in any case there should be no superelevation, there will, as a matter of fact, be nearly the full amount due to the main curve. This may affect the working of the traffic in a very serious manner. When an ordinary railway-carriage runs round a curve, the principal disturbing forces arise from centrifugal force, from the parallelism of the axles, and from the difference of length between the outer and inner rails.[1] The first can be completely balanced by superelevation of the outer rail. The second and third can be abolished by the use of radial axles and one wheel loose on the axle (as in the rolling-stock used on the old railway over the Mont Cenis Pass and elsewhere); but the difficulty of making the moving parts so that they will stand rough usage and heavy traffic is so great, and the inconvenience to be avoided is so small when the wheel-base is short, that the system has not found favour, though it has lately been suggested by Mr. Farr [2] as a cure for other evils. The effect, such as it is, of the second and third disturbing forces is to cause the leading wheel to hug the outer rail and try to mount it, and this can be roughly if unscientifically corrected by giving a slightly increased amount of superelevation. If this is introduced, then with bogie stock there would appear to be very little danger in running round quick curves at a high speed, provided only the amount of superelevation is not so great as to be a source of danger at low speeds, or when standing still. A speed of 25 miles an hour on a 5-chain curve seems well within the limits of safety. It may well be, however, that while there is no danger in traversing a quick curve, there may be great danger in entering it on a tubular railway without transition curves. Assuming a 5-chain curve, a speed of 25 miles an hour, a super-

[1] See the Author's remarks in the discussion of Mr. Adams' Paper on "Train Resistance," Minutes of Proceedings Inst. C.E., vol. xxxi. p. 394.

[2] Minutes of Proceedings Inst. C.E., vol. cxli. p. 88.

elevation of 7 inches, and a side-shift of 8 inches to obtain this, there will be a point on the short intermediate straight where there is a superelevation of 5 inches or 6 inches; and this is the point where derailment is most likely to occur, when the train will appear to run off the rails on the inside of the curve. In the case of the accident at Amberswood Junction in July, 1900, the Board of Trade Inspector mentioned among the contributory causes that of running at 30 miles an hour round an 8½-chain curve with practically no superelevation, and this does not seem to be any more objectionable than running along a straight with 6 inches of superelevation on one rail, or running along a flat curve with superelevation on the wrong rail. It is apparent, therefore, that it is much more difficult and less efficacious to ease off the junction of straight line and curve by rule of

Figs. 3.



thumb in the case of a tube than in the open, and that the safe speed for trains depends, not upon the radius of the curves, but upon the method of entering them; and as the maximum speed at certain points may indirectly affect the time of transit of the trains to a very large extent, the introduction of transition curves, in laying out the tube, so that the rails may be laid as indicated in *Fig. 3* (*b*), may materially affect the commercial success of the whole undertaking.

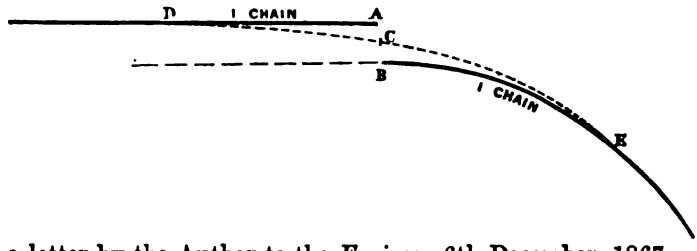
In conclusion, the Author would call attention to two points connected with the introduction of transition curves in the open, since, though not always necessary, they are often useful and in some countries their use is compulsory. The first is that

2 minutes is a full allowance for the time required to introduce such a curve in setting out, and the second is that if these curves are to be used, they must be introduced at the original setting-out of the line. For ordinary purposes, all transition curves should be of one length, say 2 chains (if 100-foot chains be used a length of 200 feet may be adopted). The amount of shift is one-third of the deviation of the main curve from the straight in a length of 1 chain, or :—

$$\text{Shift in feet} = \frac{11}{\text{radius of curve in chains}},$$

say 9 inches for a 15-chain curve, 13 inches for a 10-chain curve, etc. The straight line is set out to the tangent-point A, *Fig. 4*, the shift A B is put in, the curve is laid out as a circle from the point B, a peg is put in half way at C, and the work is done. The transition curve will run from D to E, and the platelayer will always put in a good curve. This matter is more fully dealt with

Fig. 4.



in a letter by the Author to the *Engineer*, 6th December, 1867. A moment's consideration will show that although 9 inches seems a very small matter in the original setting-out, it would be impossible to set out the rails eventually 18 inches nearer one side of a cutting than the other, and hence it is futile to attempt to put in transition curves in setting out the rails if they have not been allowed for in setting out the work originally. In the case of such curves in tunnels and stations, and more particularly in tubes, where points have to be given at shorter intervals than 1 chain, the matter must be gone into more fully, and for this purpose there can be no better guide than the Paper on "Transition Curves for Railways,"[1] by Mr. James Glover, recently published by the Institution.

The Paper is accompanied by drawings, from which the Figures in the text have been prepared.

[1] Minutes of Proceedings Inst. C.E., vol. cxl. p. 161.

(Paper No. 3295.)

"American Passenger Locomotives."

By FREDERICK JAMES LEIGH, Assoc. M. Inst. C.E.

THE continual increase in the speed and weight of passenger trains, which has taken place in the United States during the last 10 years, has been followed by the construction of locomotives of greatly increased power and weight.

The engines used are of three leading types:—

1. "Eight-wheel" engines, having four coupled wheels and a leading four-wheel truck, Figs. 1 and 2, Plate 3.

2. "Atlantic" type engines, having four coupled wheels, a leading four-wheeled truck, and a pair of trailing carrying-wheels, Figs. 3 and 4, Plate 3.

3. "Ten-wheel" engines, having six coupled wheels and a leading four-wheeled truck, Figs. 5 and 6, Plate 3.

The "eight-wheel" engine is the simplest and cheapest to build, is convenient to repair and is easy on the track, but the demand for boilers of large steam-raising capacity has led to the adoption of the "Atlantic" type of locomotive. The "ten-wheel" engine is used when the trains are heavy and the stops frequent. Only 10 years ago, a passenger-engine weighing 49 tons[1] was considered heavy; now the weight has reached over 62·5 tons for "eight-wheel" engines, and 80·35 tons for "Atlantic" and "ten-wheel" engines. In the year 1893, when the New York Central and Hudson River Railroad built an "eight-wheel" express engine, with 37·5 tons weight on the driving-wheels, such a weight on four wheels was considered extraordinary. Many engines now have 40·18 tons on four driving-wheels, or about 10 tons on each wheel. The most recent "Atlantic" express engines of the Pennsylvania Railroad have about 46·87 tons on the four driving-wheels, or about 11·71 tons on each wheel.

In the table of particulars of locomotives given in the Appendix, it will be noticed that the tractive force of the "eight-wheel" and

[1] The British *ton* of 2,240 lbs. is used in this Paper.

"Atlantic" engines varies between 20 per cent. and 26 per cent. of the weight on the driving-wheels, and that the tractive force of the "ten-wheel" engines varies between 19 per cent. and 21 per cent. of the weight on the driving-wheels. The high ratio of tractive force to weight on the driving-wheels of many recent engines is rendered allowable by improved methods of applying sand to the wheels. The adhesion of the driving-wheels to the rails can be greatly increased by these methods of sanding, and the maximum tractive force can be used to start the load or to get over short lengths of wet or slippery road. The diameter of the driving-wheels of four-coupled engines has gradually been increased from about 6 feet 6 inches to a maximum diameter of about 7 feet, with the resulting advantages of lower speed of working parts, better steam distribution, and a reduced weight of counterbalance. The driving-wheels of "ten-wheel" engines vary between about 5 feet 9 inches and 6 feet 8 inches in diameter. The driving wheel-base of "eight-wheel" engines is usually about 8 feet 6 inches to 8 feet 9 inches, and the total wheel-base is about 24 feet 6 inches. The driving wheel-base of "Atlantic" engines is usually about 7 feet to 7 feet 6 inches, and the total wheel-base is about 27 feet. In "ten-wheel" engines the driving wheel-base is usually about 14 feet to 14 feet 6 inches, and the total wheel-base about 26 feet.

The construction dimensions of American railroads limit the extreme height of the locomotive from rail-level to about 15 feet, and the extreme width to about 10 feet 3 inches. Owing to the increased diameter of the driving-wheels and to the large size of the boilers, the centre-line of the boiler is about 9 feet above rail-level in modern engines. Special efforts are being made to obtain great and long-sustained power at high speeds. To effect this, great attention is being paid to the provision of large boilers, large and direct steam-passages and easily-moving slide-valves, and to the details of the valve-gear. At the present time the leading question with American locomotive engineers is that of fire-box design. Closely connected with this subject, and to a considerable extent dependent upon it, are those of the arrangement of the wheels, the length of the tubes, and the height of the boiler from the rail. From carefully-made experiments, it has been found that the rate of combustion in locomotives burning bituminous coal has been forced to uneconomical limits. In many cases, rates of over 150 lbs. of coal per square foot of grate per hour have been reached. The general opinion appears to be that the rate should not exceed 100 lbs. of coal per square foot of grate per hour. It has therefore become necessary to increase

the size of the grates, in order to provide the power required for modern engines without raising the rate of combustion to unreasonable limits.

When the conditions of service only required a grate-area of about 18 square feet, this could be obtained by placing the fire-box between the front and rear driving-wheels longitudinally, and between the frames transversely. The maximum size of grate thus obtainable for an engine having a driving wheel-base of 9 feet, was about 6 feet 6 inches in length by 2 feet 10 inches in width. As engines increased in power and more grate-area was required, the grate was extended over the rear driving-axle. The next step was to carry the fire-box foundation-ring over the top of the frames, bringing the sides of the fire-box casing as near to the wheels as possible. With this arrangement a grate of about 3 feet 4 inches in width can be obtained, which, with a length of 9 feet 6 inches, gives an area of 31·6 square feet. Grates up to 10 feet in length are used for engines burning bituminous coal, but to properly fire such a long grate severely tries the powers of even a very strong fireman. In engines burning anthracite coal, it has for many years been the practice to extend the grate in width, by carrying the boiler foundation-ring over the top of the frames. Wide fire-boxes similarly extended are now rapidly coming into use for engines burning bituminous coal, and it seems possible that they will be generally adopted. With the wide fire-box it is possible to reduce the grate to a convenient length, and at the same time to provide a grate-area large enough to keep down the rate of combustion to an economical limit. A lighter fire can be carried, and a lower grade fuel can be burnt, without making a dirty fire. The work of the fireman is easier, and there is less emission of smoke and sparks from the smoke-stack. It is also claimed that the square form of grate enables the coal to be burnt with greater economy than on the long and narrow grate. Wide fire-boxes burning anthracite coal are made comparatively shallow, and can be placed over driving-wheels of fairly large diameter without raising the boilers too high. This, however, is not possible with the deeper fire-box required to burn bituminous coal, and in this case the "Atlantic" type of engine has been adopted. The four driving-wheels are placed under the boiler barrel, and a pair of trailing carrying-wheels are placed under the wide fire-box. Recent "Atlantic" engines are built with supplementary outside frames, which provide a wider support for the fire-box and allow outside bearings to be used for the trailing carrying-wheels. This arrangement is reported to have improved the riding of the engines.

In the year 1897 a committee of the American Railway Master Mechanics Association reported upon the ratio of grate-area and heating-surface to cylinder-volume, and submitted, as the result of their investigations, that for engines burning bituminous coal the ratio of grate-area, in square feet, to the total cylinder volume in cubic feet, should not be less than 3 to 1, and that the ratio of heating-surface in square feet to the total cylinder-volume in cubic feet should not be less than 200 to 1. These ratios are now being much exceeded, the grate-area being proportioned to suit the quality of coal to be used, rather than to the cylinder-volume or heating-surface. Recently built "eight-wheel" engines, with narrow fire-boxes, have the ratio of grate-area to total cylinder-volume as high as 3·89 to 1, and of heating-surface to total cylinder-volume 305 to 1. In the case of "Atlantic" engines with wide fire-boxes, the ratio of grate-area to total cylinder-volume is as high as 5 to 1, and of heating-surface to total cylinder-volume 337 to 1. For "simple" engines the boiler steam-pressure is usually between 185 lbs. and 200 lbs. per square inch. For "compound" engines it is 200 lbs. to 210 lbs. per square inch.

Fire-boxes are always of steel. The fire-box crowns are usually stayed with some form of direct screwed stay, very few fire-box crowns being fitted with crown-bars. Belpaire fire-boxes are used to a considerable extent. Boilers of the "extended wagon top" type are most general. These boilers have the top of the fire-box casing raised to provide a deep fire-box, with sufficient water- and steam-space above the fire-box crown. The raised portion is extended some distance along the barrel, and is connected to the front end of the barrel by a taper course. The dome is placed on the "wagon top." The large wide-fire-box boilers are usually built with straight tops. Many are built with sloping back-sheets, which lightens the boiler at the back end, giving a more effective fire-box heating-surface, and allowing more room in the cab. The boiler-tubes are either of iron or steel, and are usually 2 inches in diameter. In recent years the length of 2-inch tubes has been increased to 14 feet, 15 feet, and in some cases to 16 feet. The strong draught, high rate of combustion, and high velocity of the escaping gases have made the use of such long tubes permissible. The tubes are swaged down slightly at the fire-box end, and are fitted outside with copper ferrules, having a thickness of about No. 18 Standard wire-gauge. When the tube is expanded, this copper ferrule makes a tight joint between the tube and the tube-sheet. No ferrules are used inside the tubes. The cylinders and steam-chests are always placed outside the frames. Each cylinder is cast in one piece with half of the

"saddle," on which the smoke-box rests and to which it is securely bolted. The Pennsylvania Railroad have recently departed from this practice, and have gone back to the older arrangement of casting the half "saddle" separate from the cylinders. When ordinary "D" slide-valves are used, the steam-chest is a separate casting, and is jointed to its cover and to the cylinder with copper-wire gaskets. In the Vauclain four-cylinder compound locomotive, one high-pressure and one low-pressure cylinder, the piston-valve steam-chest and half of the "saddle" form one casting. When "D" slide-valves are used, they are of the "balanced" type, and are always of cast-iron. The Richardson valve is that most generally used. In this valve the steam-pressure is prevented from acting on a considerable portion of the back of the valve by means of cast-iron packing-strips, which are maintained in contact with a rubbing-plate by suitable springs. Piston-valves are being used in many recently-built engines. It is claimed that, when properly designed, the resistance is less than with the ordinary balanced "D" valve, with the result that the strain on the valve-gear is materially reduced, the steam distribution is better, owing to the freer motion of the valve, and the valve-gear is more easily handled by the engineer. The area of the steam admission and release openings can also be much increased. There are a number of different forms of piston-valve packings in use, but the general opinion appears to be that plain split packing-rings give satisfaction. To obtain a large wearing-surface, broad rings have been used, but trouble has been experienced by the steam getting under the rings, forcing them out against the bushings, and causing excessive frictional resistance and undue wear. As the steam-chests are always above the cylinders and outside the frames, motion is given to the slide-valves through the medium of rocker-shafts. The Stephenson link-motion is used almost without exception. The slide-valves are usually set with no lead, or with negative lead in full forward gear, and are arranged to have about $\frac{1}{4}$ inch of lead when cutting off at 25 per cent. of the piston-stroke. Steam or screw reversing-gear is not used, as the "balanced" valves are easily handled with the ordinary reversing-lever.

The main frames of the engines are of the bar type, the width of the bars for the powerful engines under description being about $4\frac{1}{4}$ inches. They are usually made of iron forged from selected scrap, although cast-steel is used to some extent. If of iron, the top "rails" are forged solid in one length, and the axle-box pedestals, the bottom "rails," and the braces are welded on. The front "rail" or "rails" carrying the cylinder is bolted and keyed

to the main portion of the frame, great care being taken with the design and workmanship of this joint to ensure a thoroughly reliable connection. The cylinders, cross-stays, and other frame-connections, besides being bolted to the frames, are either lipped over or checked into the frames, thus relieving the bolts of a considerable portion of the strain. Cast-steel is now used for the driving-wheel centres instead of cast-iron, a considerable reduction in weight being thus effected. Cast-steel axle-boxes with brass bearings are generally used, a brass liner being placed between the axle-box and the hub of the wheel to prevent undue wear. Cast-steel is also used for many other details instead of wrought- and cast-iron, and every means is adopted to save weight, in order that as large a boiler as possible may be employed. The driving-wheel springs of "eight-wheel" and "ten-wheel" engines are connected by equalizing levers, arranged to give an equal distribution of weight on the driving-wheels. In "Atlantic" type engines the driving-wheel springs and the springs of the trailing carrying-wheels are connected by equalizing levers, the lever arms being proportioned to transfer the desired portion of the weight to the trailing carrying-wheels. The leading four-wheel trucks used for passenger-engines are usually fitted with centres swinging on links, which, in addition to the circular motion, allow a certain amount of side play.

Considerable difference of opinion exists with respect to the height of the blast-pipe orifice in the smoke-box. For some years it was the rule to have the top of the blast-pipe at about the level of the top row of tubes. In the year 1896 a committee of the American Railway Master Mechanics Association reported upon this matter, and a number of railways have followed their recommendation to use a low blast-pipe, combined with "petticoat" or draught-equalizing pipes. Smoke-boxes are fitted with netting or perforated plates for the purpose of arresting dangerous sparks that may have passed through the tubes. The smoke-boxes are extended in length to contain the spark-arresting devices. The very long smoke-boxes in use a few years ago have met with disapproval, and only a moderate extension is now used. A "self-cleaning" smoke-box, in which the sparks are beaten to pieces against the netting, and are then passed out of the smoke-stack in harmless particles, is used on many roads, instead of the longer box which holds the cinders until the end of the run. Although spark-arresting devices are still used as a matter of precaution, endeavours are made to obtain more perfect combustion of the fuel in the fire-box, and thereby reduce the amount of cinders drawn through the tubes. In recent engines, having increased grate-area, the rate of

combustion has been much reduced, and the lighter draught has had the good effect of preventing, to a great extent, the drawing of cinders through the tubes. It has been found that, with unduly high rates of combustion, the losses in sparks amounted, in some cases, to 10 per cent. or 15 per cent. of the total amount of coal fed into the fire-box.

The use of compound locomotives is increasing in the United States, and the general opinion appears to be that they have now passed the experimental stage and are gaining in favour. There is a growing tendency to use compound engines for fast, heavy passenger-trains. The Vauclain four-cylinder compound engine is the type generally used in passenger service. These engines have a high-pressure and a low-pressure cylinder on each side, placed in one vertical plane, the high- and low-pressure piston-rods being connected to one cross-head. The piston-valve is placed between the cylinders and the smoke-box. It is double and hollow, and controls the steam distribution of both cylinders. The exhaust steam from the high-pressure cylinder passes through the valve to the opposite end of the low-pressure cylinder. For starting the engine, high-pressure steam can be admitted to the low-pressure cylinder as well as to the high-pressure cylinder. This is done by a by-pass valve, which is opened to allow steam to pass from one end of the high-pressure cylinder to the other, whence it passes through the piston-valve to the low-pressure cylinder. The by-pass valve is worked from the cab by the same lever that operates the cylinder waste-water valves. The ratio of the piston areas is about 2·8 to 1. The minimum cut-off in the high-pressure cylinder is arranged to occur at about half-stroke. When running, the starting-valve can be opened and high-pressure steam admitted to the low-pressure cylinder; but this is only done in case of emergency, when, after putting the valve-motion into full gear, the engine is in danger of sticking. The greatest economy is considered to be attained by compound engines when they are worked continuously up to their full load.

It may be stated generally that the engines, of which particulars are given in the Appendix, attain an average speed of 45 miles to 50 miles per hour, that the "eight-wheel" and "Atlantic" engines haul trains of 250 tons to 400 tons weight, and that the "ten-wheel" engines haul trains of over 500 tons weight. These weights do not include that of the engine and tender.

The Paper is accompanied by a drawing, from which Plate 3 has been prepared, and by the following Appendix.

[Appendix.

APPEN

American Passenger

Railway.	Type.	Simple or Compound.	Cylinders.	Diameter of Driving Wheels.	Boiler Pressure per Square Inch.	Tractive Force.[2]
			Inches. Diam Stroke.	Feet. Ins.	Lbs.	Lbs.
Chicago and North Western . . .	Eight-wheel	Simple	19 × 26	6 8	190	18,900
Boston and Albany	,,	,,	20 × 26	6 3	190	22,400
New York Central and Hudson River . . .	,,	,,	19 × 24	6 5	200	19,100
Chicago and North Western . . .	Atlantic	,,	20 × 26	6 8	200	22,100
Pennsylvania . .	,,	,,	20½ × 26	6 8	185	21,500
Burlington, Cedar Rapids, and Northern . .	,,	,,	19½ × 26	6 3	210	23,500
New York Central and Hudson River . . .	,,	,,	21 × 26	6 7	200	24,600
Philadelphia and Reading[1] . .	,,	Vauclain 4-cylinder compound	13 & 22 × 26	7 0½	200	..
Baltimore and Ohio	,,	Vauclain 4-cylinder compound	15 & 25 × 28	6 6	200	..
Wisconsin Central	Ten-wheel	Simple	19 × 26	5 9	200	23,100
Lake Shore and Michigan Southern	,,	,,	20 × 28	6 8	210	25,000
New York Central and Hudson River . . .	,,	,,	20 × 28	6 3	200	25,400
Michigan Central .	,,	,,	20 × 28	6 3	200	25,400
Chicago, Rock Island, and Pacific . . .	,,	Vauclain 4-cylinder compound	15½ & 26 × 28	6 6½	200	..
Union Pacific . .	,,	Vauclain 4-cylinder compound	15½ & 26 × 28	6 0	200	..
Delaware, Lackawanna and Western[1] . .	,,	Simple	20 × 28	5 9⅜	210	28,900

[1] *Anthracite* coal burners.

[2] Mean effective pressure =

DIX.

LOCOMOTIVES.

Weight		Heating Surface.			Grate Area.	Total Volume of Cylinders.	Ratios.			
On Driving Wheels.	Total.	Fire-box.	Tubes.	Total.			Grate Area to Cylinder Volume.	Heating Surface to Cylinder Volume.	Heating Surface to Grate Area.	Tractive Force to Weight on Driving Wheels.
Tons.	Tons.	Sq. Ft.	Sq. Ft.	Sq. Ft.	Sq. Ft.	Cub. Ft.	Sq. Ft. / Cub. Ft.	Sq. Ft. / Cub. Ft.	Sq. Ft. / Sq. Ft.	Lbs. / Lbs.
38·26	59·73	173·68	2179·71	2353·39	30·33	8·52	3·56	276	77·6	0·22
39·51	60·89	178·74	2326·53	2505·27	30·33	9·46	3·2	265	82·6	0·25
42·14	65·35	180·0	2224·0	2404·0	30·7	7·88	3·89	305	78·3	0·20
40·18	71·43	170·7	2845·18	3015·88	[3]46·2	9·46	4·88	319	65·2	0·245
46·87	80·35	160·0	2270·0	2430·0	[3]51·0	9·92	5·14	245	47·7	0·205
39·28	70·80	155·8	2396·0	2551·8	[3]45·32	8·98	5·04	284	56·3	0·267
42·41	78·57	180·0	3325·17	3505·17	[3]50·32	10·4	4·84	337	69·6	0·259
35·09	63·84	190·2	1614·9	1805·1	[3]76·0	..	..	..	23·7	..
37·23	66·78	150·0	2513·0	2663·0	[3]42·5	..	..	..	62·6	..
51·78	66·96	189·0	2111·0	2300·0	32·4	8·52	3·8	271	70·9	0·20
59·37	76·69	223·0	2694·0	2917·0	33·6	10·2	3·29	286	86·8	0·188
59·91	78·12	170·0	2745·0	2915·0	30·5	10·2	2·99	285	95·5	0·189
60·71	77·94	200·7	2924·18	3124·83	34·63	10·2	3·39	306	90·2	0·187
60·07	80·03	180·5	2569·6	2750·1	32·8	..	..	..	83·8	..
63·59	82·25	186·0	2825·0	3011·0	32·0	..	..	..	94·1	..
61·16	79·91	180·0	2520·0	2700·0	[3]84·2	10·2	8·25	264	32·1	0·21

85 per cent. *of boiler-pressure.*

[3] Wide fire-boxes.

(Paper No. 3269.)

"A Comparison of the Flow of Water in a River with that in a Small-Scale Model of the River."

By THOMAS ALFRED HEARSON, M. Inst. C.E.

ABOUT 25 years ago, Froude pointed out that there were reasons, resting on theoretical considerations, which justified the belief that the results of experiments, made to determine the resistance which the model of a vessel would meet with in its progress through water, may be used to determine the resistance which the ship itself would encounter, if a particular scale of comparison, which he then enunciated, were adopted. He afterwards, by a famous set of experiments, demonstrated the relation between the resistances of ship and model. He proved that if a facsimile of the vessel, the linear dimensions of which are $\frac{1}{n}$ of those of the full-size ship, be towed through water at a speed equal to $\frac{V}{\sqrt{n}}$, the resistance will be $\frac{1}{n^3}$ of that which the full-size ship would meet with at a speed V. Since that time the resistance of all important vessels having new proportions has been determined, before the vessels were built, by experiments on their models; and these experiments have paved the way for important advances in naval architecture.

An examination of the several elements of resistance to the flow of water in a river appears to show that if a facsimile of the river is provided on a scale of $\frac{1}{n}$, with the depth of water everywhere $\frac{1}{n}$ of that in the river, and therefore the slope of the water surface the same in each, then the velocity at every point in the section of the model stream will be $\frac{V}{\sqrt{n}}$ of that in the river, so that, if

the volume of flow down the model stream, found by the use of measuring-tanks or otherwise, is Q, the corresponding volume of discharge of the river will be $n^2 \sqrt{n}$ Q, being greater in the ratio, first of n^2 to 1, which is that of the cross-sectional areas, and secondly, in the ratio $\sqrt{n}$ to 1, which is that of the two velocities.

The three important elements of resistance to the flow of water along a river-bed are (1) surface friction; (2) variation of the sectional area of the stream; (3) deviation of the line of the stream.

Surface Friction.—The results of experiments which have been made to determine the effect of roughness of surface are conveniently expressed by means of the formula:—

$$\text{Loss of head or fall of level} = f \frac{l}{m} \frac{v^2}{2g},$$

where v is the mean velocity of the stream, l is the length of the stream, m is the hydraulic mean depth, and f is a kind of coefficient of friction.

The numerical value of f has been made the subject of a vast amount of experiment. It naturally depends on the degree of roughness of the surface, and on this account appears to vary between a minimum value in the case of smooth surfaces, and one twice as great when the surface is as rough as it could be made without encroaching on the other elements of resistance. The value of f also depends on the hydraulic mean depth, because the velocity with which the water glides over the rough surfaces is less, in proportion to the average velocity, the larger the section of the stream. The experiments seem to show that, with a moderate degree of roughness, excluding on the one hand very smooth surfaces not found in natural rivers, and on the other hand surfaces so rough as to introduce the other elements of resistance, f varies between a minimum value when the section is very large, and one twice as great when the section is quite small, but not small enough to introduce the element of viscosity resistance to a marked degree. These two considerations taken together appear to indicate that, if the roughness of the surface were diminished proportionally with the hydraulic mean depth, the tendency of f to increase from one cause would be counteracted by the tendency to decrease due to the other cause, so that its value may be expected to remain constant, or nearly so. The value of f depends also on the slope of the stream, but since the slope is assumed to be the same in river and model, no discrepancy will arise from this. If the roughness of the bed

of the river could be accurately copied in a model on a scale of $\frac{1}{n}$, and the slope of the water surface were maintained the same in each, then f would probably have the same value for both river and model. The ratio $\frac{l}{m}$ will also have the same value for both, and if the velocity in the model were kept equal to $\frac{1}{\sqrt{n}}$ of that in the river, the loss of head or fall of level between any two points in the model stream would be $\frac{1}{n}$ of that in the corresponding length of river. It follows conversely that if the gradient in the model is the same as that in the river the velocity in the model will be $\frac{1}{\sqrt{n}}$ of that in the river.

Variation of the Sectional Area of the Stream.—The loss due to this cause has, by experiment, been found to depend on the ratio of enlargement and to be proportional to the square of the velocity of flow. Hence for this cause also, if the velocity in the model is $\frac{1}{\sqrt{n}}$ of that in the river, the loss of head in the model will be $\frac{1}{n}$ of that in the river; and conversely, if the hydraulic gradient is the same in both model and river, *i.e.*, the loss of head due to a change of section at any portion of the model is $\frac{1}{n}$ of that at the corresponding portion of the river, then the velocity past this obstruction in the model will be $\frac{1}{\sqrt{n}}$ of the river velocity at the corresponding point.

Deviation of the Line of the Stream.—Precisely the same thing is true with respect to bends and deviations of the line of flow. The loss of head depends on the angle of deviation if abrupt, and, if not abrupt, on the ratio of the radius of curvature of the bend to the hydraulic mean depth, together with the angle of deviation. The value of either of these quantities for a deviation in the model will be the same as for the corresponding deviation in the river. The loss of head due to this cause is proportional also to the square of the velocity of flow, so that on account of this cause also the velocity of flow in the model stream will be $\frac{1}{\sqrt{n}}$ of that in the river.

The element of resistance due to the viscosity of the water is

not subject to the same law of being proportional to the square of the velocity, and its effect in the model will be proportionately greater than in the river; but, by avoiding the use of very small models, the discrepancy due to this effect will probably be found to be negligible. With the velocity relation which has been previously described, the tendency to produce a standing wave in the river will be faithfully copied in the model; also, inasmuch as the velocity of progression of a wave travelling over shallow water is proportional to the square root of the depth, the same law of kinetic similarity will cause wave-formation in the river, due to wind or other disturbing effect, to be copied in the model, the height and period of the waves in the model being respectively $\frac{1}{n}$ and $\frac{1}{\sqrt{n}}$ of those of the waves in the river. Again, if a tidal wave at the estuary of the river is produced artificially in the model to a scale of $\frac{1}{n}$ in respect of height, and $\frac{1}{\sqrt{n}}$ in respect of period, its rate of progress up and down the river will follow the same law of kinetic similarity.

In Froude's experiments, the form of the disturbing surface had to be pulled through the water, which was at rest, and considerable invention and mechanical skill had to be exercised in devising and using the apparatus in order to obtain a sufficiently accurate result. In the experiments which the Author proposes, the forms of the disturbing surfaces, viz., the banks and bed of the river, are at rest, and the water is permitted to gravitate past them. So far, a comparison of the difficulties and the expectation of getting successful results are in favour of the model river experiments as against those with model ships. On the other hand, Froude had the considerable advantage due to the greater simplicity of the ship-shape form of the disturbing surface. He had to apply a correction, the scale of which required much experiment to determine, in order to eliminate a discrepancy in the results due to the mere difference of lengths of model and ship. This cause of error appears to be absent in the model river experiments, unless an equivalent error is introduced when a short portion only of the river is modelled, and the two end conditions of that portion are not faithfully copied.

Probably the most important question for consideration, after that as to the soundness of the theory of comparative velocities, is whether the practical difficulties of making a sufficiently accurate

model of a river, with respect to the roughness of its bed as well as to its varying sections and its windings, could be fairly easily surmounted. The following method may be adopted for the purpose of copying the roughness of the bed of the river on the reduced scale. Let a number of samples of the loose material be procured from the bed of the river, and, by being passed through screens and sieves of known and graduated width of mesh, be divided into a number of separate volumes, in which all the pieces in any one mass are of approximately the same diameter. Let also a quantity of sand be obtained and sifted through a graduated series of fine sieves, so that it is divided into a similar set of masses, in which the diameter of the particles in any one mass is $\frac{1}{n}$ of that of a corresponding mass of the river detritus. In this way, for each volume of river material an equivalent volume of sand could be obtained, having a degree of fineness which is $\frac{1}{n}$ of that of the former. If the whole is duly mixed and distributed over the bed of the model river, the roughness of the river-bed will be copied with a fair degree of ease and accuracy on the scale of $\frac{1}{n}$.

By providing loose material in the bed of the model, which, on the reduced scale, is similar to that in the river, another important feature in the behaviour of the river could be submitted to examination by experiments on its model, viz., the tendency to erode or silt up its bed.

The force available for the transport of loose material, consisting of particles of like shape similarly situated on the bed or in the section of the stream, may be expected to be proportional to the momentum of the mass of water which, in the unit of time, will come within the range of influence of the particles. The transporting force will accordingly be proportional to the transverse section of the particle, multiplied by the velocity to get a measure of the mass, and again by the velocity to get the momentum. Thus, if the section is proportional to $\frac{1}{n^2}$, and the velocity to $\frac{1}{\sqrt{n}}$, the momentum will be proportional to $\frac{1}{n^3}$. At the same time the gravity effect, or excess of weight over buoyancy, will, for particles of the same density of material, be proportional to the volume, and therefore also proportional to $\frac{1}{n^3}$. Accordingly,

the relative magnitude of the transporting and depositing forces will be the same in the river and in the model, so that, if the depth of water in the model stream and the consequent velocity be such as to hold any particular set of particles in suspension, and cause them to be conveyed, then the corresponding depth of water in the river and the accompanying velocity would cause the corresponding set of particles in the river, which are n times the size, to be likewise conveyed.

In 1887, Professor Osborne Reynolds [1] proposed experiments with models of the estuaries of rivers in order to arrive at information relative to the regime of the sand-bed under tidal influence. Experiments were made in subsequent years by the British Association under the direction of Professor Reynolds. The scale adopted in the model was much greater for depth than for horizontal dimensions. In one set of experiments the depth scale was $\frac{1}{180}$, and the horizontal scale was $\frac{1}{20,000}$, the period of the wave being duly modified. Larger scales were precluded on account of the difficulty, cost, and length of time which would be involved in producing a sufficient succession of artificial waves to get the sand into a permanent regime. The model results showed a remarkable accordance with Nature's results, in spite of the smallness of the scale of the model and the complication of the distorted scale of dimensions. The sand used was of a very fine description, but apparently was not chosen to represent the sand of the estuary on any particular scale. The law of kinetic similarity, on which a justification for belief in the results of the experiments was founded, was derived from the well-known fact that the velocity of a wave in shallow water is proportional to the square root of the depth of the water. It is therefore almost exactly comparable with Froude's law, so that the successes of Froude and Reynolds seem to encourage a hope of success for experiments with model rivers under suitable conditions.

On a piece of flat land adjoining the river, over which a stream of water could be diverted, a model of comparatively large scale could be readily constructed by digging out the bed and building up the banks. To copy the accession of water to the river by springs in its bed, a small side feeding-stream could be provided for the model river. The criterion of similar percolation would be found in similar hydraulic gradients in river and model.

If an attempt is made to experiment on the whole length of a river in a model of moderate size, the actual smallness of the

[1] Report of the British Association, 1887, p. 555.

lateral dimensions, especially the depth, and the smallness of the velocity, may be found to introduce errors in copy, and errors from the effect of viscosity, etc., which would vitiate the results. The difficulty may be surmounted by experimenting on a portion of the length at one time, on a larger scale. The stretch of river selected should begin and end in fairly straight reaches, in which there is a moderately permanent regime, so that the end conditions may with more certainty be introduced in the model. A verification of the accuracy of the results or otherwise would be derived by constructing two models, one on a smaller scale than the other. Should only a small discrepancy be observed, the cause could perhaps be traced, and a scale of correction determined, as between the two models, which might be extended to include the river itself.

If it is admitted that the theory is likely to prove correct, and that the construction of the models is feasible, there remains the question of the usefulness of such experiments. In reply to this, it may be pointed out that the damage done by floods, and the cost of the engineering works which are required to mitigate the evil, as well as the doubtfulness of their effect and of their permanence, are often so great that the comparatively small cost of producing the flood on a small scale and trying various methods of abatement on the model, preparatory to the execution of the work on the actual river, would probably be well repaid.

The combination of the flow of a high spring-tide up a river with a discharge downwards of a large quantity of land water is a fruitful cause of flooding of the banks of the lower reaches of a river, and many questions relating thereto, such as the value of deepening the bed of the river below tide-level, and the degree of tendency for it to silt up, remain unanswered, or the answers are matters of opinion only. Also the effect of holding back the land water by reservoirs during the flow, and allowing it to escape during the ebb of the tide, could be tried. In tropical countries there are streams which almost suddenly swell from small rivulets into overwhelming rivers. By means of a small-scale model the place of the most imminent danger of such a river breaking its banks might be discovered, and, by anticipation, the consequent flood and ruin prevented. There are doubtless other points, in regard to which information might be provided by experiments on models.

(Paper No. 3277.)

"Note on the Deflection of a Beam with Overhanging Ends."

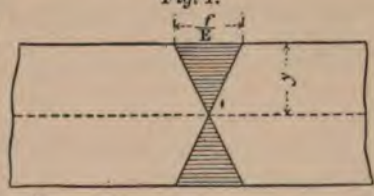
By JOHN MAURICE SIMEON WOORE, B.E., Assoc. M. Inst. C.E.

IN the following Paper the Author deduces some general expressions for the deflection of a beam of uniform section with overhanging ends,[1] under different systems of loading, having been led to consider the subject while engaged in the design of certain timber bridgework, when it became necessary to find the deflection at the ends of such a beam.

In an interesting and suggestive book on "Statically Indeterminate Structures and the Principle of Least Work," by Mr. H. M. Martin, it is proved[2] that if U represents the total work done in deforming an elastic structure, the deflection at the point of application of any load W will be $\Delta = \frac{d\,U}{d\,W}$. In the case of a beam of uniform section, it can be proved that the total work done in bending[3] the beam is $U = \frac{1}{2\,E\,I}\int_o^l M^2\,d\,x$, where l is the length of the beam and M the bending-moment at any point.

The work done at any point is equal to the average moment of resistance at that point multiplied by the angle through which it is exerted, or, referring to *Fig. 1*:—

Fig. 1.



Work done at any point $= \frac{f\,I}{2\,y}\cdot\frac{f}{y\,E} = \frac{f^2\,I^2}{2\,y^2\,E\,I} = \frac{1}{2\,E\,I}\,M^2$,

and $$U = \frac{1}{2\,E\,I}\int_o^l M^2\,d\,x.$$

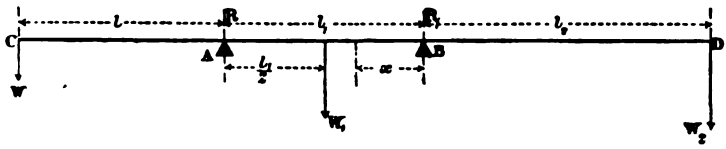
[1] A graphical method of treating this problem is to be found in Professor Fidler's "Practical Treatise on Bridge Construction," 2nd ed., p. 129.

[2] p. 21.

[3] The work done in shearing is inconsiderable, in comparison, and may be neglected.

Deflections produced by Concentrated Loads.—In *Fig. 2* is represented a beam of uniform section, supported and held down at two points, A and B, at a distance l_1 apart, having overhanging

Fig. 2.



ends A C and B D of lengths l and l_2, and loaded with three concentrated loads W, W_1, and W_2. To find the deflection at the end D,

let u = work expended in bending in length l

„ u_1 = „ „ „ „ l_1

„ u_2 = „ „ „ „ l_2

The bending-moment at any point between B and W_1 is equal to $R_1 x - W_2 (l_2 + x) = \frac{W_2 l_2 x}{l_1} + \frac{W_1 x}{2} - \frac{W l x}{l_1} - W_2 l_2$,

R_1 being the reaction at B. The square of this expression must be taken in calculating the value of u_1, but it will only be necessary to include those terms which contain powers of W_2 as the others vanish when $\frac{d u_1}{d W_2}$ is taken.

These terms are:—

$$\frac{W_2^2 l_2^2 x^2}{l_1^2} + W_2^2 l_2^2 + \frac{W_1 W_2 l_2 x^2}{l_1} - \frac{2 W W_2 l l_2 x^2}{l_1^2} - \frac{2 W_2^2 l_2^2 x}{l_1} - W_1 W_2 l_2 x + \frac{2 W W_2 l l_2 x}{l_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

Similarly the bending-moment at any point between A and W_1 is equal to—

$$\frac{W l x}{l_1} + \frac{W_1 x}{2} - \frac{W_2 l_2 x}{l_1} - W l.$$

The terms in the square of this expression which contain powers of W_2 are—

$$\frac{W_2^2 l_2^2 x^2}{l_1^2} - \frac{2 W W_2 l l_2 x^2}{l_1^2} - \frac{W_1 W_2 l_2 x^2}{l_1} + \frac{2 W W_2 l l_2 x}{l_1} \quad . \quad (b)$$

Adding (a) and (b) the sum is—

$$\frac{2 W_2^2 l_2^2 x^2}{l_1^2} + W_2^2 l_2^2 - \frac{4 W W_2 l l_2 x^2}{l_1^2} - \frac{2 W_2^2 l_2^2 x}{l_1} - W_1 W_2 l_2 x + \frac{4 W W_2 l l_2 x}{l_1} = a, \text{ say.}$$

Then $$u_1 = \frac{1}{2\,E\,I}\int_o^{l_1} a\,d\,x + \frac{1}{2\,E\,I}\int_o^{l_1} a^1\,d\,x$$

where a^1 represents the terms that have been neglected, *i.e.*, those not containing powers of W_2.

Also $$u_2 = \frac{1}{2\,E\,I}\int_o^{l_2} W_2{}^2\,x^2\,d\,x,$$

and u may be neglected, as it does not contain terms in W_2; so that the work required is equal to

$$\frac{1}{2\,E\,I}\int_o^{l_1} a\,d\,x + \frac{1}{2\,E\,I}\int_o^{l_2} W_2{}^2\,x^2\,d\,x,$$

which is equal to

$$\frac{1}{2\,E\,I}\left(\frac{W_2{}^2\,l_1\,l_2{}^2}{12} + \frac{W_2{}^2\,l_1\,l_2{}^2}{2} - \frac{W\,W_2\,l\,l_1\,l_2}{6} - \frac{W_2{}^2\,l_1\,l_2{}^2}{4} - \frac{W_1\,W_2\,l_1{}^2\,l_2}{8} + \frac{W\,W_2\,l\,l_1\,l_2}{2} + \frac{W_2{}^2\,l_2{}^3}{3}\right)^* = U^1, \text{ say,}$$

and the deflection at the end D $= \delta_2 = \dfrac{d\,U^1}{d\,W_2}$

$$= \frac{1}{2\,E\,I}\left(\frac{2\,W_2\,l_1\,l_2{}^2}{3} + \frac{W\,l\,l_1\,l_2}{3} - \frac{W_1\,l_1{}^2\,l_2}{8} + \frac{2\,W_2\,l_2{}^3}{3}\right). \quad . \quad (1)$$

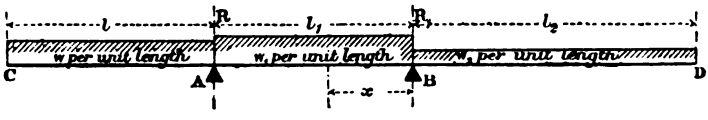
The deflection at W_1 may be derived in a similar manner by retaining only those terms in the expression for U which contain powers of W_1, and differentiating with respect to W_1.

Thus the deflection at $W_1 = \delta_1$

$$= \frac{1}{2\,E\,I}\left(\frac{W_1\,l_1{}^3}{24} - \frac{W_2\,l_1{}^2\,l_2}{8} - \frac{W\,l\,l_1{}^2}{8}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Deflections produced by Uniformly Distributed Loads.—In *Fig. 3* let the sections C A, A B and B D be uniformly loaded with loads of w, w_1, and w_2 per unit length, respectively. The deflection at the

Fig. 3.



end D, due to the loading of span l, may be immediately derived from the corresponding expression for a concentrated load, *i.e.*,

* The constants in this and the following integrations are obviously = 0. These will therefore not be further considered.

$\frac{1}{2\,E\,I} \cdot \frac{W\,l\,l_1\,l_2}{3}$. Substituting w and x for W and l, the required deflection $= \frac{1}{2\,E\,I}\int_o^l w\,l_1\,l_2\,x\,dx = \frac{1}{2\,E\,I} \cdot \frac{w\,l^2\,l_1\,l_2}{6}$. For the deflection at the end D, due to $w_1\,l_1$ and $w_2\,l_2$, assume a subsidiary load W_2 to be applied at D; this load will be made equal to zero in the final result.

It is obvious that only those terms of U which contain W_2 will survive in the expression for deflection, as the terms in W_2^2 will finally disappear when W_2 is made zero. The required terms in the squares of the bending-moment are—

$$\frac{W_2\,w_2\,l_2^3\,x^2}{l_1^2} - W_2\,w_1\,l_2\,x^2 + \frac{W_2\,w_1\,l_2\,x^3}{l_1},$$

and $$W_2\,w\,x^3.$$

Integrating,

$$\frac{1}{2\,E\,I}\int_o^{l_1}\left(\frac{W_2\,w_2\,l_2^3\,x^2}{l_1^2} - W_2\,w_1\,l_2\,x^2 + \frac{W_2\,w_1\,l_2\,x^3}{l_1}\right)dx + \frac{1}{2\,E\,I}\int_o^{l_2} W_2\,w\,x^3\,dx = \frac{1}{2\,E\,I}\left(\frac{W_2\,w_2\,l_1\,l_2^3}{3} - \frac{W_2\,w_1\,l_1^3\,l_2}{12} + \frac{W_2\,w_2\,l_2^4}{4}\right),$$

and differentiating with respect to W_2 the result is—

$$\frac{1}{2\,E\,I}\left(\frac{w_2\,l_1\,l_2^3}{3} - \frac{w_1\,l_1^3\,l_2}{12} + \frac{w_2\,l_2^4}{4}\right),$$

and the total deflection at the end D $= \delta_2$

$$= \frac{1}{2\,E\,I}\left(\frac{w_2\,l_1\,l_2^3}{3} + \frac{w\,l^2\,l_1\,l_2}{6} - \frac{w_1\,l_1^3\,l_2}{12} + \frac{w_2\,l_2^4}{4}\right) \quad . \quad . \quad . \quad (3)$$

The deflection at the centre of the span A B may be obtained by assuming a subsidiary load W_1 to be applied at the centre; then by retaining only those terms of U which contain W_1, and differentiating with respect to W_1, the deflection is found to be—

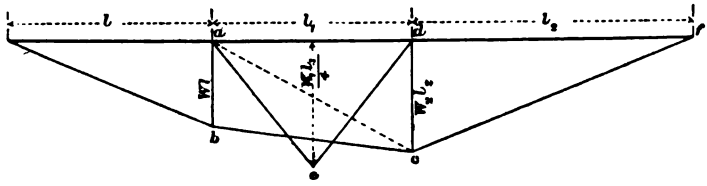
$$\delta_1 = \frac{1}{2\,E\,I}\left(\frac{w_1\,l_1^4}{192} - \frac{w\,l^2\,l_1^2}{16} - \frac{w_2\,l_1^2\,l_2^2}{16}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

As a check, the deflection at the end D will be worked out by the graphic method which is fully explained in Professor Fidler's "Practical Treatise on Bridge Construction." It is there proved[1] that the deflection of a beam of uniform section $= \frac{G\,X}{E\,I}$,

[1] Second edition, p. 131.

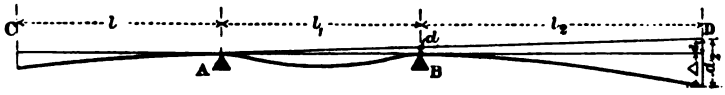
where G is the area of that part of the bending-moment diagram between the point of contact of the tangent from which the deflection is measured, and the point at which the deflection is required; and X is the distance of the centre of gravity of this

Fig. 4.



area from the point at which the deflection is required. In the case of concentrated loads (*Fig. 4*), taking moments of the areas

Fig. 5.



a b c, *a c d*, and *a e d* about *d*, the deflection at B of the tangent drawn from the point A (*Fig. 5*) is found to be—

$$d = \frac{1}{E\,I}\left(\frac{W\,l\,l_1^2}{3} + \frac{W_2\,l_1^2\,l_2}{6} - \frac{W_1\,l_1^3}{16}\right),$$

and the corresponding deflection at D

$$= d_1 = d\left(1 + \frac{l_2}{l_1}\right) = \frac{1}{E\,I}\left(\frac{W\,l\,l_1^2}{3} + \frac{W\,l\,l_1\,l_2}{3} + \frac{W_2\,l_1^2\,l_2}{6} + \frac{W_2\,l_1\,l_2^2}{6} - \frac{W_1\,l_1^3}{16} - \frac{W_1\,l_1^2\,l_2}{16}\right).$$

Also taking moments of the areas *a b c*, *a c d*, *a e d* and *d c f* about *f* (*Fig. 4*), the deflection d_2 (*Fig. 5*) is found to be—

$$d_2 = \frac{1}{E\,I}\left(\frac{W\,l\,l_1^2}{3} + \frac{W\,l\,l_1\,l_2}{2} + \frac{W_2\,l_1^2\,l_2}{6} + \frac{W_2\,l_1\,l_2^2}{2} + \frac{W_2\,l_2^3}{3} - \frac{W_1\,l_1^3}{16} - \frac{W_1\,l_1^2\,l^2}{8}\right),$$

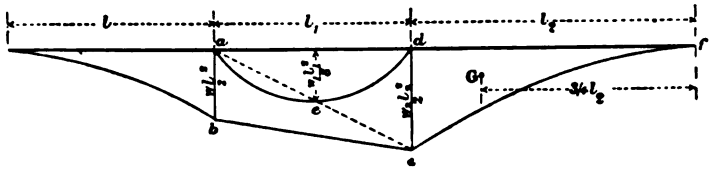
and the deflection from the horizontal at the end D

$$= \Delta = d_2 - d_1 = \frac{1}{2\,E\,I}\left(\frac{2\,W_2\,l_1\,l_2^2}{3} + \frac{W\,l\,l_1\,l_2}{3} - \frac{W_1\,l_1^2\,l_2}{8} + \frac{2\,W_2\,l_2^3}{3}\right),$$

which is the same as that found before.

In the case of uniform loads, taking moments of the areas $a\,b\,c$,

Fig. 6.



$a\,c\,d$ and $a\,e\,d$ about d (*Fig. 6*), the deflection d (*Fig. 5*) is found to be

$$d = \frac{1}{E\,I}\left(\frac{w\,l^2\,l_1^2}{6} + \frac{w_2\,l_1^2\,l_2^2}{12} - \frac{w_1\,l_1^4}{24}\right),$$

and

$$d_1 = d\left(1 + \frac{l_2}{l_1}\right) = \frac{1}{E\,I}\left(\frac{w\,l^2\,l_1^2}{6} + \frac{w\,l^2\,l_1\,l_2}{6} + \frac{w_2\,l_1^2\,l_2^2}{12} + \frac{w_2\,l_1\,l_2^3}{12} - \frac{w_1\,l_1^4}{24} - \frac{w_1\,l_1^3\,l_2}{24}\right).$$

Also taking moments of the areas $a\,b\,c$, $a\,c\,d$, $a\,e\,d$, and $d\,c\,f$ about f (*Fig. 6*) the deflection d_2 (*Fig. 5*) is—

$$d_2 = \frac{1}{E\,I}\left(\frac{w\,l^2\,l_1^2}{6} + \frac{w\,l^2\,l_1\,l_2}{4} + \frac{w_2\,l_1^2\,l_2^2}{12} + \frac{w_2\,l_1\,l_2^3}{4} - \frac{w_1\,l_1^4}{24} - \frac{w_1\,l_1^3\,l_2}{12} + \frac{w_1\,l_2^4}{8}\right),$$

and the deflection from the horizontal at the end D is

$$\Delta = d_2 - d_1 = \frac{1}{2\,E\,I}\left(\frac{w_2\,l_1\,l_2^3}{3} + \frac{w\,l^2\,l_1\,l_2}{6} - \frac{w_1\,l_1^3\,l_2}{12} + \frac{w_2\,l_2^4}{4}\right),$$

which is the same as the expression found previously.

The Paper is accompanied by diagrams, from which the Figures in the text have been prepared.

(Paper No. 3294.)

"Peat Fuel in Scandinavia."

By Alfred Bache, B.A., Assoc. Inst. C.E.

The high price of coal has recently elicited no less than thirteen almost contemporaneous and mainly independent articles on the subject of peat fuel, in the three leading Scandinavian engineering periodicals, Swedish, Norwegian, and Danish. These are summarized in the following Paper, in separate groups for each of the three countries. As the several writers naturally go over much the same ground, their views are abridged in the endeavour to avoid repetition. The outline now given may be useful in particular to those interested in the development of the peat industry in Ireland; and reference may be made to a Paper on the manufacture of compressed peat fuel, read before the Institution of Mechanical Engineers[1] on the occasion of their meeting in Dublin, when the members visited the Derrylea Peat Works, near Portarlington, where an open-ended press was in operation, which seems to have been the precursor of the similar press mentioned by Mr. Larsson as now employed at Ironowka.

Swedish Views on Peat Fuel.[2]

As the possible yield of the great Swedish peat bogs is estimated to be equivalent to 3,000 million tons of coal, Mr. Hakon Brunius urges that this vast store of fuel should no longer be so neglected as hitherto. Probably high railway freights and weather unfavourable for such a material have thus far prevented the industry from flourishing. But the conditions are altered by the present high price of coal, which justifies the maintenance of existing factories for making peat briquettes, and the building of new works,

[1] Proceedings, 1865, pp. 147–164.

[2] Teknisk Tidskrift, Stockholm, 1900, 3 November, p. 311; 1 December, pp. 334 and 336; 15 December, p. 345; 29 December, p. 359; 1901, 23 March, p. 49; 27 April, p. 63; 11 May, p. 121.

wherever sufficient supplies of peat are at hand. Coal imports during 1899 amounted to about 70 million kronor (£3,900,000), and for 1900 are expected to reach 100 million kronor (£5,500,000), which might as well be spent in Sweden as abroad. The moulding of the peat into briquettes is not the chief feature in the utilization of this fuel. For works immediately adjoining peat bogs, mere pressing and drying may suffice. Where however carriage becomes a consideration, and also for household use, the briquettes are best. Peat is an ideal fuel, firm, hard, clean to handle, devoid of smell, and therefore highly suitable for the kitchen. The Swedish briquettes are superior to those made in Germany; the great difference in weight, colour, and heating power, is remarkable.

An exhibition of peat fuel, held at Jönköping in connection with a meeting of the Swedish Peat Cultivation Society, comprised twenty-four varieties, besides a sample made from the white moss obtained from the experimental field at Flahult. Three kinds of peat briquettes were shown, one Swedish by Lithander, one German, and one Dutch, as well as a collection of samples of the products of peat distillation, such as peat charcoal, peat tar, gas oil, creosote oil, sulphate of ammonia, and peat spirit; and drawings of the method devised by Mr. Wilén of Gothenburg for manufacturing peat charcoal, accompanied by specimens of the peat and of the charcoal produced therefrom.

At a meeting of the Peat Cultivation Society Mr. Alf. Larsson dealt with the importance of peat fuel to Sweden, and the best methods of converting peat into good fuel. During the last 10 years the importation of coal has more than doubled in weight, and has trebled in cost, to the disadvantage of the revenue. For the year 1900 the quantity imported is estimated at about 3,200,000 tons, while the home production of coal is only 250,000 tons a year, and cannot easily be increased. In almost all stationary furnaces peat can now be substituted for coal, having for 10 years past been employed in Martin-steel and glass furnaces, brick and tile kilns, and others; and in 1900 it has been shown that, in steam boilers with furnaces large enough, and with careful firing, as much steam can be produced per square foot of heating surface with peat as with coal. In Finland, Russia, and Germany, locomotive and marine boilers also are fired with wood or peat while in shed or harbour. Apart from this use Mr. Larsson considers that roundly 1,500,000 tons of coal per annum might now be replaced by peat, which for equivalent heating power would amount to $1{,}500{,}000 \times 1{\cdot}8 = 2{,}700{,}000$ tons, with a saving of 50 million kronor (£2,700,000) at the present

In 1896 it was reported by the peat engineer of the

ironmasters' association that already 1,000,000 tons of peat were manufactured annually, mostly for metallurgical purposes, and principally in the midlands of Sweden. The production could now doubtless be trebled, especially as in the southern districts the weather is more favourable for peat manufacture. At the very lowest price of coal, namely 15 kronor (16*s.* 8*d.*) per ton delivered in harbour, the equivalent price of peat having a heating power bearing to that of coal the ratio of 1 to 1·8 would be 8½ kronor (9*s.* 3*d.*) per ton. The cost of manufacture is 3 to 6 kronor (3*s.* 4*d.* to 6*s.* 8*d.*) per ton, according to the quality of the bog; and freight charges are alike on peat and on coal. Even with coal at the exceptionally low price of 11 kronor (12*s.* 3*d.*) per ton a few years ago, the peat works were not only kept going, but were also enlarged. Wood should be reserved for better purposes than burning as fuel. Its price is continually rising, the forests are becoming more and more depleted in the midlands and south of Sweden, and the timber cut down is not being replaced by fresh growth. The present yearly consumption is not less than 247 million cubic feet, which, if only fir loppings, would weigh 2,415,000 tons, equivalent in heating value to 1,800,000 tons of peat. Hence there need be no fear of any falling off in the demand for peat.

As to the best method of manufacturing peat fuel, the most efficient Mr. Larsson has yet seen is that carried on by Mr. Van Bremen at Haarlem, in the province of Holland, where the whole land lies below sea-level. The bogs he is working, having formerly been meadows, are covered with sand and clay to a depth of 1 foot to 1 foot 8 inches. This, when removed, is either deposited on the portion reserved for a drying-floor, thereby raising the latter to a level of 1 foot to 1 foot 8 inches above the water-level; or else is utilized for throwing up dikes round those parts of the bog that are higher than the surrounding land previously cleared of peat and now under cultivation. When ultimately the drying-floors themselves have to be removed for getting the peat from under them, the overlying layer of earth is deposited in the bog ditches. The lease of a bog requires that it shall be completely cleared of peat and drained dry within 30 years. A water company undertake to pump dry the portion that is being worked, and to build necessary sluices. The peat bed varies in thickness between 5 feet and 6 feet 6 inches; the latter thickness yields only 800 tons per acre of air-dried peat containing 25 per cent. water. The rent of the bog comes to at least 1·8 gulden (3*s.*) per ton. The peaty mud is scooped up by a floating exca-

vator, consisting of a large iron lighter which carries a steam-engine with scooping and kneading apparatus. Twelve such excavators, each turning out daily 100 tons to 200 tons of peat reckoned as air-dried, are collectively raising 50,000 tons of dry peat per annum. The depth of water in which they float on the bog is a little over 1 foot. They deliver the kneaded peat to the drying-floors at an all-round cost of 1·8 gulden (3*s.*) per ton. It is spread out in a layer 2 feet thick, which dries down to half its thickness in a couple of days. It is then cut up into blocks 3 inches square and 5½ inches long, which are stood on end. The quantity dried per acre is 400 tons of dry peat per annum. After the drying, the rest of the work—treading, cutting, piling, carrying, stacking, and thatching—is professedly done by the landlord, who however is often unable to pay for doing it, in which case it is done by the lessee, who takes payment in peat, reckoned at 8 to 8·5 gulden (13*s.* 4*d.* to 14*s.* 2*d.*) per ton.

Two such excavators, each costing 30,000 kronor (£1,700), are working on Ageröd bog in Skåne, and it is found essential for success that the peat should be kneaded to a stiffer consistency and laid out to dry in moulds. At Sparkjœr in Jutland 18,000 to 20,000 tons per annum are turned out, partly by floating and partly by stationary appliances. The bogs are deep, well rotted, and almost free from stumps and roots. One man digs per day of 10 hours the equivalent of 10 to 12 tons of dry peat. The dry peat there weighs 28 to 31 lbs. per cubic foot, and costs to manufacture on the bog 2½ to 3 kronor (2*s.* 9*d.* to 3*s.* 4*d.*) per ton. Floating excavators are unsuitable for bogs containing any considerable quantity of stumps, roots, or root-fibre.

Near Amsterdam a bog of 860 acres, visited by Mr. Larsson in the spring of 1899, was being worked by five excavators, supplemented by an attendant barge carrying a chain-pump or bucket-elevator. The kneaded peat raised from the last plots, where there was no room for depositing it, was loaded into the barge, conveyed away to some other part of the bog, and there carried up by the elevator to the drying-floor. The annual output was 20,000 tons. The best plan, he considers, would be to let each dredger work in a straight line right through the whole length or breadth of the bog, and deliver the stuff alongside as far inland as the spout can reach; and thence to take it away in trucks on rails, as is done at Sparkjœr, Stafsjö, and elsewhere. Dredging begins on 1 April and ends on 20 June; in fine weather the day's work is 15 hours, from 4 A.M. to 7 P.M. A lump of peat 1·56 cubic

was raised by one excavator five times in 2 minutes;

1 cubic metre (1·3 cubic yard) yielded 0·1 ton of dry peat. But the average raising was only 75 tons per day, and the maximum 195 tons. Each excavator required nine men. The stuff deposited to dry in layers 2 feet thick sank in 24 hours to half or a third of this thickness; it was then trodden, and after lying 2 to 8 days, according to the weather, was again trodden, cut, and heaped; in September and October it is stacked, and after the turn of the year it is dry enough for sale. The cost of manufacture, including delivery to the stores in Haarlem, was 9 gulden (15*s.*) per ton, and the selling price 10 to 11 gulden (16*s.* 8*d.* to 18*s.* 4*d.*) wholesale, and 12 to 16 gulden (20*s.* to 26*s.* 8*d.*) retail.

The dried peat is turned out of many works in Sweden and other countries in the form of briquettes and bars. The former have been manufactured for 10 years past at Ironowka, near St. Petersburg, on the plan followed in Germany with brown coal. There and elsewhere the briquettes are made direct from peat mull not previously treated mechanically, containing 35 to 60 per cent. of water; the mull is crushed between rolls, sifted through a sieve of about 0·4 inch mesh, and conveyed automatically to a drying chamber, where the proportion of water is brought down to 15 or 20 per cent. It is then pressed at about 176° F. into briquettes having a specific gravity of 1·0 to 1·2, which are loaded automatically into trucks direct from the presses. The drying chamber contains a nest of hollow cast-iron trays, arranged one above another and heated by exhaust steam. The peat mull is travelled by stirrers from the top to the bottom tray, and thence in its dried state to the press. The latter is an open-ended horizontal cylinder or tube, long enough to contain a number of briquettes. These form an even bottom, against which each newly-formed briquette is pressed, while their combined friction in the long tube offers the resistance necessary to allow of the pressure required. The production of the presses is 30 to 50 tons or more per day of 24 hours. To make good and durable briquettes the peat must contain in the process of pressing 18 per cent. of water. The heating power of the briquettes made from artificially dried mull is probably one-third greater than that of mechanically manufactured peat not so pressed, while the cost of making them is probably twice as great; but they are not on this account less suitable for use in various industries, because they are more easily stored and will withstand moisture, and can therefore be stacked out of doors without cover. They are also more sightly than the unpressed peat. Different railways are now making trials of various kinds of briquettes for firing locomotives.

The residual products from the coaling of peat are not nearly so valuable as those got from wood. Air-dried peat, containing 25 per cent. of water, does not yield more than 40 per cent. of charcoal. Its heating power is about 3,500 calories per kilogram (6,300 British thermal units per pound), of which not more than 2,800 calories (5,040 units) remain after coaling. There is thus a loss of 20 per cent. of heating power, apart from the cost of coaling. The best method of coaling peat, according to Mr. Larsson, is the Ziegler method, which is now being tried in Oldenburg. The next best is coaling in charcoal kilns. Peat powder, so thoroughly dried that even the water chemically combined with it is expelled, has been found to be a surprisingly good fuel during several years' use at Jönköping; it has the same evaporative value as coal. The cost of carriage is about the same as for coal of the same heating value. At Granefors a spare steam-boiler is fired with peat on a stepped grate, with good result and freedom from smoke.

In the south of Sweden, where there are fewer sources of water-power, but abundant peat bogs in populous districts with busy industries, the peat should not be taken into the towns for electric light and power stations and other works, but should be burnt in electric stations erected on the bogs themselves, whence current should be supplied for light and power. A 500-HP. condensing steam engine, running 12 hours a day for 300 days a year, Mr. Larsson calculates could then work at 42 kronor (£2 6*s.* 8*d.*) per HP. per annum with peat, as against 118½ kronor (£6 11*s.* 8*d.*) with coal at the present price of 25 kronor (£1 7*s.* 11*d.*) per ton in harbour; and peat so used could still compete with coal, even if the price of the latter fell as low as 8·65 kronor (9*s.* 7*d.*) per ton. On a good bog, peat can be manufactured at 4 kronor (4*s.* 5*d.*) per ton, and even less. The peat bogs supplement the waterfalls; and no country in the world is so well provided with favourable sites for power stations as Sweden, if only her natural resources are turned to good account.

All other great civilized countries being rich in coal, Mr. A. Bödtker points out that it devolves upon Sweden and Norway, which are deficient in coal but rich in peat, to solve the problem of substituting peat as fuel. The disproportionately high cost of its production, and its large bulk which renders its transport too expensive, hinder its general use. In Germany it is sought to get over the difficulty of bulk by establishing suitable branches of industry in the peat districts, and so avoiding the need of conveyance to longer distances. The chief aim will be to find

cheaper methods of trenching, cutting, and drying peat, and of manufacturing peat charcoal with its valuable by-products. The special difficulty in employing peat charcoal for iron-smelting has been that it is too friable. Moreover it often contains phosphates and other ingredients which mar the purity of the iron; these however will doubtless be deprived of their injurious influence by improved processes of manufacture. In Styria and Russia iron ore is already smelted with charcoal, made from peat that is as free from phosphate of lime as can be got. The possibility may also be contemplated of smelting iron with water-gas produced by passing steam over glowing peat-charcoal, or with peat gas; in either of these methods the purity of the iron would not be impaired.

A peat-coking kiln designed by Mr. Alb. Bergström embodies the most approved arrangements of walls with internal flues, for maintaining a uniform temperature in continuous working; and finally utilizes the spent gases for drying the peat before it is fed into the coking chambers. A detailed description of the kiln is given, with drawings.

Norwegian Views on Peat Fuel.[1]

For the investigation of this important subject of national economy the State is believed by Mr. J. G. Thaulow to contemplate getting a grant voted. Opinions are divided; many works have been carried on experimentally, and large sums have been expended. Though no really valuable result seems yet to have been attained, the present high prices of coal furnish a powerful stimulus to renewed effort. The difficulties to be contended with are, first, that crude peat contains so large an amount of water; and second, that dried peat is so bulky in proportion to its heating value. The latter objection is met by compressing the dried peat into briquettes, which, though forming a useful fuel, smell unpleasantly, unless burnt in fire-places specially arranged. A more thorough plan is to coal or coke the dried peat, thereby obtaining an ideal fuel, in which is concentrated the greatest possible heating value; it is also cleaner. Among the principal attempts lately made are the Dickson method of pressing briquettes in Canada, and the coaling processes of Ziegler in Germany, Holm in Aalborg, Denmark, and P. Jebsen in Norway. In the last-mentioned country, peat has

[1] Teknisk Ugeblad, Christiania, 1900, pp. 630 and 701; 1901, p. 277.

been called "the slumbering millions;" and the millions of tons of water contained in it have hitherto obstructed an adequate utilization of the peat bogs. To get 1 ton of dry peat, 4 tons of water have to be got rid of. Natural drying in the open air suffices for the small quantities of peat required for household use. On a larger scale artificial drying becomes necessary, involving expenditure of power and heat, both of which must be used in the best way. In coaling peat, about 40 per cent. of its dried weight is obtained as charcoal: so that 1 ton of peat charcoal represents 2½ tons of dried peat, from which 10 tons of water have been dried out. If the temperature of the air in the drying-shed averages 160° F., there will be required at least 28,000,000 British thermal units to make 1 ton of peat charcoal, which at most can develop only about 22,600,000 units. To this must be added the power supplying the current of drying air, and the heat expended in coaling the peat. Having himself been concerned for some years in artificially drying materials for various industries, Mr. Thaulow believes that with persevering effort favourable results can be realised in peat-drying. Although the climate of Norway is so much less favourable than that of Denmark for open-air drying, which, in many localities rich in peat, is altogether precluded by the great downpour in summer, yet the Norwegian cheap water-power presents a means of driving powerful ventilators; and the currents of dry air thereby produced can be so arranged as to recover and take advantage of the latent heat contained in the steam that is generated by the evaporation of the water from the peat. In this way he has himself obtained good results in Sweden and Finland with drying apparatus for wood-pulp. From his designs an experimental peat-drying house is now being built at the Stangfjord Electro-Chemical Works in Søndfjord, where the Jebsen process of manufacturing peat charcoal by means of electricity is carried out with recovery of by-products. The peat gas from the coking retorts is used as fuel, along with waste charcoal and air-dried peat blocks. The principal by-products are recovered in the following percentages of the weight of dried peat used in coaling:—Creosote oil 4 per cent., worth about £2 a ton; sulphate of ammonia 0·4 per cent. at £8 a ton; acetate of lime 0·6 per cent. at £6 a ton; methyl alcohol or wood-spirit 0·2 per cent. at £35 a ton. As soon as ever a cheap method is realised of freeing the crude peat from its large percentage of water, 50 tons per 24 hours ought to be the minimum output of dry peat from any factory.

To Norway the present dearth of coal will prove a boon, in the opinion of Mr. Adolf Dal, who is a State Peat Master, if it

stimulates the growth of the peat industry, and develops experience useful for better times. It is not advisable now, he considers, to await the complete solution of the problem of coaling peat in such a way as to obtain the best product with the greatest economy; but advantage should be taken of the present favourable opportunity for utilizing peat as commonly manufactured by machinery, short of coaling. The crude peat is kneaded in machines of various kinds, either direct from the bog or with added water; the fibres are ground asunder, squeezed together, and the less-rotted portions are torn apart and mixed with the fully-rotted portions. Hence, when it dries, the ground peat becomes much more solid and dense than that which is dried in lumps as dug from the bog; it is also more convenient for transport. Such peat made in Norwegian factories was found by Mr. Dal to have a specific gravity ranging between 0·6 and 1·1, most commonly 0·8 to 0·9; and to contain 1·96 to 8·8 per cent. of ash, generally 3½ to 5½ per cent., reckoning the percentage on thoroughly dry peat. The quality naturally varies, according as the crude material itself varies between light mossy peat but little rotted, and black rich peat. It undergoes no chemical change in the kneading machines, so that its heating power is equal to that of the crude material, and is commonly taken at 3,500 calories per kilogram (6,300 British thermal units per lb.). The peat so manufactured is useful for most firing for which coal is now used; it gets up steam and keeps it up as well as does coal; it burns up completely, leaving no clinker, and makes less smoke than coal, as it contains less carbon. Containing less sulphur, it attacks boilers less, as established by experiments. The smell is an imaginary bugbear, and occasions no annoyance in works with tall chimneys and good draught. Its greater bulk requires a somewhat different arrangement of furnace for burning it to the best advantage; but this is not an indispensable necessity. In Sweden moving grates have been tried, but Mr. Dal does not yet know with what result. In Norway such machine-made peat is used in certain industrial establishments; and abroad for firing engine-boilers. In Denmark excellent air-dried peat is manufactured for less than 3 kroner (3*s.* 4*d.*) per ton; and works provided with the best modern machinery can turn it out for 4 to 5 kroner (4*s.* 5*d.* to 5*s.* 7*d.*) a ton. Its heating power varies between 56 and 67 per cent. of that of coal; if taken as low as 50 per cent., the same heat can be got from 2 tons of peat, costing together 8 to 10 kroner (8*s.* 11*d.* to 11*s.* 1*d.*), as from 1 ton of coal. Many works using peat have

chosen sites adjoining peat bogs, getting their fuel thence direct and at the least cost for carriage, and incurring less outlay for buildings in the country.

The coaling of peat seems to Mr. Dal to be attended with no advantages. All methods hitherto made public presuppose the mechanical manufacture of peat; it is machine-made peat that is used in the Ziegler coaling-oven at Oldenburg in Germany, in the works at Øhr, and by Holm at Aalborg in Denmark. Coaling does not supersede this preliminary work; and though it affords the opportunity for recovering by-products from the gas, it is doubtful whether these recoup the cost of recovery. The Oldenburg works have had economical difficulties, and at one time came to a standstill, in spite of being situated right in one of the largest peat bogs in the world, and notwithstanding good management. Nor does coaling dispense with the inconvenience of drying the peat, which cannot be done by mechanical squeezing, because in the richest peat the water and vegetable matter are so intimately blended in a plastic dough that they cannot be separated by pressure. Even from poorer peat, any water that can be squeezed out carries off with it a not inconsiderable portion of the carbon contained in the peat. Hence air-drying is for the most part indispensable; artificial drying, as far as Mr. Dal knows, has not been carried out otherwise than experimentally. Peat charcoal should be kept for smelting works, where its freedom from sulphur enhances its value; it is not suitable for ordinary firing, for which it ought to be denser than hitherto made. Pressed peat briquettes have come more to the front since the advance made in pressing brown coal. In the Canadian process, which has made so great a stir, the peat is pressed into briquettes without undergoing any chemical change; the process involves no new methods, but probably has many advantages in successful arrangement of the machinery. Every earnest attempt to "waken the slumbering millions"—in other words, to unearth the wealth of the Scandinavian peat bogs—will be welcome. Beginnings should be made on a small scale. Mechanical manufacture of peat must form the groundwork. In Sweden, Denmark, and Germany, the first step has been to make and use manufactured peat; coaling accompanies the manufacture experimentally. In Norway the most successful course will be to increase the production of manufactured peat, which will be the means of developing a great industry.

At the Trent Valley Peat Fuel Works, Kirkfield, Canada, the peat is raised by a large dredger, previously employed in cutting a canal through the peat bog. The crude peat is conveyed in

lighters on the canal to the works; later it is intended to carry it in buckets on a wire-rope tramway. It is filled into bags of coarse felt, 6 feet by 6 feet by 4 inches, a dozen of which, separated by thin frames, are conveyed on a lorry to the hydraulic press, where the water, originally forming about 90 per cent. of the mass, is squeezed out down to about 55 per cent. under a pressure of 4,000 lbs. per square inch. The press takes in about 8 tons of crude stuff at a time, and the pressing lasts about 12 minutes. The pressed stuff goes to the drying room, where it first passes through a crushing machine, which makes about 400 revolutions per minute; the teeth of the machine sever all the larger pieces of peat, the whole of which is then fed into the upper end of a sloping cylinder, 30 feet in length and 5 feet in diameter; the cylinder revolves slowly round its axis, and terminates at its lower end in a firing chamber, wherein the temperature is about 1,500° F. The yield is about 3 tons of dried peat per hour. The peat, having become highly heated in the drying cylinder, is cooled by passing through two more crushing machines, which reduce it to powder. It now contains about 12 per cent. of moisture, and is taken to a press, which compresses it into cylindrical pieces 1½ inch long and 1½ inch in diameter. The works are understood to have cost about £12,000. The cost of manufacture is reckoned at 6*s.* 5*d.* per ton, including royalty. This industry is as yet only in its infancy, and experience is still wanting with regard both to the mode of manufacture and to the commercial value of the product.

Danish Views on Peat Fuel.[1]

Rise of wages seems to Mr. J. J. Tylvad to call for larger employment of mechanical power in the manufacture of peat, if this fuel is to be cheapened and brought into more extensive use, and at the same time to be rendered more efficient. Improvement in heating value cannot be attained by treating the raw material at ordinary temperatures; the most advantageous temperature is that which will yield a product of the highest heating value in the smallest bulk, without attendant loss of combustible ingredients; such a temperature lies between rather narrow limits, and is so high that the peat is just coaled thereby, and is no longer peat, but peat charcoal. The best mechanically kneaded peat still contains 20 per cent. of absorbed water, and about as much chemically combined with it, besides other incombustible ingre-

[1] Ingeniøren, Copenhagen, 1900, pp. 388 and 402; 1901, pp. 46, 57, 61, and 64.

dients; its specific gravity is 1·0 to 1·1 at most, and its heating power 2,800 to 3,500 calories per kilogram (5,000 to 6,300 British thermal units per lb.); the only practical gain from the special treatment employed is cheaper carriage and a pleasanter and more compact peat. While mechanical treatment is thus limited in its effect, higher temperature admits of a further advance; without loss of combustible matter, both bulk and weight can thereby be halved, and heating power doubled. Coaling gets rid almost entirely of all incombustible matters, water, and carbonic acid, which together amount to about 50 per cent. It thus leaves a perfect fuel of the least possible bulk; and there is more economy in expelling the noxious constituents by coaling the peat in a specially arranged oven, than by burning it direct in a furnace as peat without previous coaling. A ton of peat yields altogether 115,000 more calories (460,000 more British thermal units), if first coaled and then burnt as peat charcoal, than if burnt direct as peat. Since the value of peat charcoal as fuel is less variable than that of the different kinds of peat from which the charcoal is made, the kinds of peat that are more advantageous to carbonize are those containing smaller quantities of carbon, or, in other words, larger quantities of incombustible ingredients other than ash. The several practical considerations determining the alternative choice of burning the air-dried peat direct as fuel, or of first coaling it and then burning the peat charcoal so produced, are elaborately investigated, and are exemplified by figures based upon various actual conditions in regard to current costs of manufacture and rates of carriage. In a particular comparison made by Mr. Tylvad between peat and peat charcoal, their composition was found to be as follows:—

	Peat. Per Cent.	Peat Charcoal. Per Cent.
Carbon	42·7	76·5
Hydrogen	4·0	3·5
Oxygen	27·4	11·9
Nitrogen	1·6	1·3
Water absorbed	21·9	2·0
Ash	2·4	4·6

The heating value of the charcoal was calculated at 6,700 calories per kilogram (12,060 British thermal units per lb.) accurately to 3 per cent. That of the peat was similarly calculated at 3,380 calories per kilogram (6,084 British thermal units per lb.); and to this had to be added the heat liberated by dissociation of organic compounds, which however can be determined only by direct measurement with a calorimeter. Loss of combustible matter in

coking peat is reduced by performing the operation at a sufficiently low temperature. Peat deposits more soot in burning than does peat charcoal.

If a boiler furnace burning coal has to be altered for burning peat, what enlargement must be made in the transverse area of the flues, in order that the boiler may take up the same quantity of heat in the same time, and so maintain the same supply of steam? This question Mr. G. F. Barfoed answers by taking account of the volume of the products of combustion from coal and from peat, and of their highest and lowest temperatures in the flues; their specific gravity and specific heat are assumed to be the same. The formula he arrives at, and the data he adopts, give 1·00 to 0·93 as the ratio of the volume from peat to the volume from coal, if the gases are completely cooled down to 32° F. But if the needful chimney draught requires that they should not be cooled below 750° F., this ratio becomes 1·00 to 0·79. With the former ratio therefore the transverse area of the flues would have to be enlarged by 8 per cent. for burning peat; and with the latter by 27 per cent. The same ratios apply also to the combustion chamber.

That peat can be converted into charcoal without loss of combustible matter is doubted by Professor N. Steenberg. It is not only water and carbonic acid that are driven off in coking; but, however slow the process, as soon as ever the actual carbonizing begins (at about 350° F.) some tar is formed, smoke becomes visible, and the condensed water always contains a little acetic acid and methyl-alcohol; moreover among the uncondensed gases are combustible substances, such as carbonic oxide, and a little marsh gas (CH_4) mixed with the carbonic acid. While it is true that peat also contains such an amount of endothermic compounds as augments its calorific value to the extent of generally about 10 per cent. beyond what is calculated from analysis of its elements, yet these compounds partly disappear in carbonizing; so that the augmentation for freely-burning peat-charcoal becomes only about 5 per cent. When peat charcoal can be produced at prices near those mentioned by Mr. Tylvad, namely 8 to 9·25 kroner (say 9*s.* to 10*s.* 4*d.*) per ton, it will not fail to be used. It yields excellent gas both for lighting and for heating, and is an excellent fuel for household use. Heating gas from peat itself is too largely mixed with carbonic acid and steam to be suitable for gas-engines; and even though it can be considerably improved by cooling it sufficiently to get rid of the water, it is yet inferior to that obtained from peat charcoal.

(*Paper No. 3236.*)

"Water-Supply on the Yilgarn Railway, Western Australia."

By WILLIAM HERBERT SHIELDS, B.Sc., Assoc. M. Inst. C.E.

THE water-supply for the Yilgarn Railway, besides being the pioneer waterworks for the inland portion of Western Australia, possesses many features of special interest. The Yilgarn Railway comprises the whole of that portion of the Government railways running eastward from Northam or Spencer's Brook. It was constructed in sections, viz., Northam to Southern Cross, 170 miles; Southern Cross to Kalgoorlie, 139 miles; and Kalgoorlie to Menzies, 89 miles, with branches to Boulder and Kanowna. When the construction of the Yilgarn Railway was begun in 1893 the last supply of water for engine purposes was obtained from the Burralong pool, a water hole in the Avon River 2 miles from Northam (the Avon, like many other Australian rivers, only flows during the winter months, and some years not even then), leaving a length of 400 miles of railway, extending into a streamless and practically unknown country, to be provided for.

At the time the railway was started the probable traffic was estimated at one train in each direction per week, and although during the progress of the work on the Southern Cross contract the traffic showed considerable promise, the maximum traffic provided for in the conservancy of water was six trains in each direction per week. Owing to the sudden influx of population after the discovery of gold at Coolgardie a minimum of ten and an average of about twenty engines have, however, to be watered daily.

The only available statistics were the rainfall at Northam, for 12 years, which varied between 8·3 inches and 20·7 inches per annum; that at Mooranoppin (a sheep station 66 miles east of Northam), for 5 years, showing a variation between 8·4 inches and 17·4 inches; and the Southern Cross rainfall, for 4 years, varying between 5·2 inches and 15·1 inches. These statistics are shown in the Appendix, Tables I and II.

As a preliminary step a surveyor was sent along the line of the work to search the country on either side for sites for reservoirs and wells. He reported:—

(1) That a well might be sunk at the Horse Valley, about

20 miles from Northam, as the water appeared to collect there from the adjacent sandhills.

(2) That a tank might be excavated at the foot of Cunderdin Hill, about 38 miles from Northam. This hill consists of a granite and dolerite ridge, the highest point of which rises about 400 feet above the surrounding country. The total natural catchment area draining into the proposed site was about 267 acres.

(3) That a tank might be excavated near the base of Kellerberrin Hill, 66 miles from Northam, a rocky conical eminence rising about 300 feet above the country to the eastward. By the aid of drains the water from about 20 or 30 acres could be collected and pumped to the proposed siding, a mile away.

(4) That at Merredin, 102 miles from Northam, a large rock existed, about 20 acres of which drained into a rock valley about 6 feet to 14 feet deep, filled with detritus from the rock. The surveyor proposed to clean out this hollow, and build a concrete wall across the lower end to form a basin.

(5) That at Burracoppin, 116 miles from Northam, about 30 acres of rock were drained by a small creek. Here the surveyor proposed to excavate a tank in the clay, $\frac{1}{4}$ mile from the rock, and to divert the creek into it.

(6) That at Parker's Road, 156 miles from Northam, a rock existed, and a tank might be excavated somewhere in the neighbourhood. The rock was on the north side of the line, but the best holding ground was on the south side.

About the time the foregoing meagre information was put into the resident engineer's hands (September, 1893) the Author was sent from Perth to act as his assistant. After consideration of the information obtained the following conclusions were arrived at:—

(*a*) That it would be advisable to construct several reservoirs, because no natural waters existed throughout the whole year.

(*b*) That before depending on wells it would be necessary to obtain further particulars concerning the existing surface supplies.

(*c*) That the combined annual evaporation and absorption in good holding ground over fairly shallow water would exceed the annual rainfall by about 7 feet, and that this loss would be distributed throughout the year somewhat in the following manner:—

	Per Cent.		Per Cent.
January	16	July	3
February	14	August	3
March	9	September	6
April	6	October	9
May	4	November	12
June	3	December	15

(*d*) That to cope with the evaporation the surface exposed should be as small as possible, and the greatest convenient depth should be chosen.

(*e*) That after allowing 14 feet for evaporation and absorption for the period, the tanks should contain 2 years' supply, and consequently the minimum depth allowed for the tanks should be 20 feet. This storage was deemed necessary on account of the precarious rainfall, the scarcity of statistics, and the unexplored and uninhabited condition of the country.

(*f*) That where the rainfall was not known, but was not likely to be affected by any local element, it should be taken as diminishing gradually from the coastal range inwards, at the rate of about 1 inch for every 30 miles.

(*g*) That where no regular record of the rainfall had been kept the following distribution should be assumed, viz. :—

	Per Cent.		Per Cent.
January	0	July	27
February	0	August	19
March	0	September	11
April	1	October	3
May	6	November	0
June	28	December	5

The quantity and distribution of the rainfall was computed from records kept in various parts of the colony, and the evaporation from statistics for somewhat similar climates. Experiments have since proved the allowance for evaporation and absorption to be fairly accurate, and further confirmation is supplied by the following information extracted from the *West Australian* of 8 April, 1899—more than 4½ years after the estimate was made—given on the authority of Mr. W. E. Cooke, the Government astronomer. The evaporation in inches per month, due to the action of the sun and wind, from a freely exposed surface of water at Perth and Coolgardie respectively was found to be as follows :—

Month.	At Perth.	At Coolgardie.
	Inches.	Inches.
November, 1898	7·18	11·12
December, „	10·12	14·88
January, 1899	11·45	12·28
February, „	10·10	11·40
March „	7·46	10·89

Total for summer at Perth, 46·31 inches ; at Coolgardie, 60·57 inches.

The total fall of rain during this period at Perth was 1·50 inch and at Coolgardie 3·60 inches. The greatest amount of evaporation in 24 hours during the summer at Perth was 0·48 inch on 9 March, and at Coolgardie 0·65 inch on 30 December and 5 February. The records show that excessive evaporation does not always accompany great heat, the maximum temperature on the days of greatest evaporation in each month being:—

Month.	At Perth.	At Coolgardie.
	°F.	°F.
November . . .	79·0	86·1
December . . .	80·9	80·8
January . . .	74·2	94·0
February . . .	101·0	101·2
March	80·8	99·6

Thus it will be seen that two record days only had a temperature of 80·8° in each instance.

The method adopted by the Author to carry out experiments on evaporation was to float a tin vessel, about 15 inches in depth, in a reservoir, the vessel being filled to within 1 inch of the top and submerged to the same depth in the water of the reservoir, the whole being kept afloat and protected from the ripples by being surrounded by an annular wooden float awash with the water and 2 feet in breadth.

It was recommended by the resident engineer that the water should be distributed from three or four large tanks, having a capacity of, say, 6,000,000 gallons each, instead of from a larger number of smaller tanks, and the sites proposed for these were Cunderdin, Kellerberrin, Merredin, and Parker's Road, the well at Burracoppin being used as an adjunct to the Merredin supply.

During January, 1894, work was commenced on a tank at Parker's Road under the supervision of one of the departmental officers. The construction was carried out by day labour, and was completed, at a cost of about £7,000, in June of the same year. This officer recommended building the contour drains on the rocks, of slabs of stone set on edge and cemented together and to the rock, instead of constructing them of concrete as proposed by the resident engineer. An improvement on this type was afterwards adopted very generally. About the month of May in the same year the Government let a contract, to the contractor for the railway, for the construction of tanks of 6,800,000 gallons

and 7,470,000 gallons capacity at Cunderdin and Merredin, the contract prices being £3,000 and £3,500 respectively. About the time these tanks were completed it was determined to buy the contractor's tank at Kellerberrin. This was effected for the sum of £1,200, and a number of improvements to it were immediately put in hand under the Author's supervision. The puddle banks on the rocks were replaced by stone walls; the bottom of the tank was taken out to a uniform depth; the sides were straightened and the banks raised; pitched by-washes were put in at the previous bank level; the portions of the banks likely to come in contact with running water were pitched with granite set in cement, all other portions being covered with 9 inches of metal broken to a 2½-inch gauge, and the whole tank was fenced.

In 1895 the Author formulated a scheme, which he was directed to carry out, for bringing water into the Cunderdin, Parker's Road, and New Zealand Gully tanks. This involved enlarging and draining the catchment areas at Cunderdin and Parker's Road, filling in the costeen pits and alluvial diggings, and draining the catchment area at New Zealand Gully. Work was begun in November at Cunderdin and in January, 1896, at Parker's Road and New Zealand Gully. In nearly all cases contour drains were run, having a fall of 6 inches per chain, the country draining into them through existing creeks or drains having a very steep fall. The Author deemed this to be necessary on account of the friable nature of the soil and the long intervals of fierce heat and drought, not infrequently lasting for months. At Cunderdin it was thought advisable to drain about 40 acres of rock and other gathering ground located in the adjoining valley. To accomplish this a tunnel, 38 chains in length, had to be driven through the separating ridge. The rocks were walled in, and were connected to each other, and finally to the approach to the tunnel, by a large open drain pitched with granite set in cement where it passed through sandy soil or along embankments. By working simultaneously at fourteen faces with three shifts of men this part of the work was completed early in March, 1896, and during a heavy fall of rain in that month the reservoir, the capacity of which was increased during the construction of the tunnel from 6,800,000 gallons to 12,200,000 gallons, received 8,000,000 gallons of water. The catchment area was increased from 267 acres to 550 acres. The catchment area at Parker's Road was similarly drained and enlarged from 187 acres to 1,150 acres.

During the progress of this work the Author was entrusted to

formulate a water-supply scheme for the Parker's Range goldfields, and in May, 1896, contracts were let for the construction of reservoirs for Spencer's Brook Junction (where the goldfields line leaves the Perth to Albany line) and for Northam, and were placed in the Author's charge. In December, 1896, the Author was called upon to prepare a scheme to keep the traffic working during the summer, the water then being on the verge of depletion. He recommended that six new reservoirs should be constructed between Northam and Southern Cross, viz., at Grass Valley, 11 miles from Northam; Tammin, 52 miles; Doodlekine, 76 miles; Hines Hill, 89 miles; Burracoppin, 116 miles; and Bodallin, 140 miles, and that the catchments at Kellerberrin and Merredin be increased from 35 acres and 50 acres respectively to over 1,000 acres. Three of these reservoirs were constructed during 1897. Five out of the six water services were gravitation supplies, and the sixth, that proposed for Hines Hill had only sufficient fall to bring the water to the station, where a pump was to be fixed on the main to force the water into the overhead tank, thus saving the expense of carting coal to the reservoir site, about 4 miles distant.

The three reservoirs constructed were carried out by day labour. These were one of 47,000,000 gallons capacity at Tammin, one of 8,700,000 gallons at Burracoppin, and one of 15,000,000 gallons at Bodallin. A sum of £25,000 was authorised for the three reservoirs. They were practically completed in about 6 months.

From Fremantle, on the coast, to Perth, the capital of the colony, the country traversed by the railway consists of coralline limestone and sand hills, diversified with an occasional swamp. Between Perth and Guildford the limestone is scarcer and the swamps more numerous. About 100 yards west of the Swan Bridge at Guildford the railway leaves the sand country, and, crossing the river, continues its way over clay flats, on which are numerous brickfields, to Bellevue (23½ miles), at the foot of the Darling range. Between Bellevue and Spencer's Brook the railway traverses rugged ranges of wooded hills consisting of granite, ferruginous gravel, and trap rock, which rise about 2,000 feet above the level of the recent deposits on the coast-line. Between Spencer's Brook and Northam the line passes through the Avon valley, between granite hills, intercepted by quartz and trap dykes. The railway next follows the Mortlock river for about 5 miles, then extends through somewhat similar country up the Grass Valley Brook, and shortly after passing the quartz ridges at the head of this creek, some extensive sand plains —undulating country covered with scrub—are crossed. From

this point onwards the country traversed may be briefly described as forest and undulating sand plains, with here and there a granite mound rising above the surrounding country. Several salt river-beds are also crossed.

The rainfall on the coastal belt averages about 36 inches, falling principally between May and October. In the Darling ranges the rainfall varies between an average of about 40 inches near the western slope and 15 inches on the eastern slope, and this also practically all falls between May and October. Between Northam and Southern Cross the rainfall diminishes from 15 inches to 9 inches, and from this point onwards there is a slight falling off in the annual rainfall; but as a larger portion falls in heavy showers during the summer months—November to April—the chances of conserving water are better than between Northam and Southern Cross.

Throughout the whole of the distance between Fremantle and Menzies no perennial stream of importance is crossed. The Fremantle water-supply for both the town and the railway is pumped from wells and adits in the prison-yard. In Perth the water for town and railway is drawn partly from a storage reservoir of about 308,000,000 gallons capacity in the Darling range, and partly from artesian wells sunk in the town. At Midland Junction (22 miles) the supply of water for railway purposes is obtained from an artesian bore with a storage reservoir of 11,750,000 gallons for use in case of emergency. From this bore was obtained the first supply of artesian water in the colony. In this connection geologists had expressed the opinion, based on the absence of springs on the land, and the knowledge that large submarine springs occurred along the coast, that the gravel beds of the ranges and the inland plateau had direct communication with the ocean, and that consequently it could not be expected that artesian water would be obtained from these water-bearing beds. The Engineer-in-chief, however, argued that, given an easy egress, the friction on a few hundred feet of pipes discharging not very much above sea-level would prove less than the friction due to 20 miles or more of gravel beds. Acting on this belief he had a bore sunk about the end of 1894, and the success attending it proved the correctness of his theory.

Chidlows Well, which is situated near the top of the steep climb up the Darling range and about 40 miles from Fremantle, was, until the end of 1897, dependent entirely on two wells for water for railway purposes. Towards the close of the summer of 1895–96 the Author was called upon to report on the possibility

of increasing the supply of water at Chidlows wells, which, during that summer, had not nearly met the railway requirements, necessitating the haulage of water from Fremantle up the 1 in 30 gradients of the old line or the 1 in 40 gradients of the new line. As it was doubtful whether the deepening of the wells would increase the supply to anything like the 50,000 gallons to 100,000 gallons daily that might be required, he recommended that water should be conserved by damming one of the numerous creeks in the neighbourhood. Towards the end of December, 1896, the surrounding country was explored, and what appeared to be the best site for a reservoir was selected. At the junction of two creeks, about 1½ mile north of the station and 120 feet below it, the existence of a natural spur projecting from the north side of the valley only required the construction of a bank 340 feet in length in order to enclose 117,000,000 gallons of water; the by-wash being placed on the spur the discharge would be kept quite clear of the bank. The bank was made 10 feet wide at the top, the water slope being 3 to 1 and the down-stream slope 2 to 1. The water slope was overlaid normally, to a depth of 1 foot, by the ferruginous gravel which covers the slopes of the hills, thus allowing a little over 3 feet of gravel in a horizontal direction to withstand the wash. A puddle wall was constructed the whole length of the bank, and was continued beyond each end until the good holding ground attained the level of the top of the bank. This central core, which was carried 3 feet above water-level, was 4 feet wide on the top, and increased in width with a batter of 1 in 12 on each side down to the ground-level. At the width there attained it was carried down about 18 inches into the sound clay, a central band 3 feet wide being carried down another 3 feet to key the puddle wall into the impervious foundation, and to prevent creep of water round the bottom of the puddle. When rock was met with, a cement concrete wall, 1 foot wide and 1 foot high, was built on the rock foundation along the centre of the puddle trench. No engineering difficulties were experienced at this site, which was in the middle of a jarrah forest, within easy reach of the town. The flooded area contained an abundance of clay, gravel, and good retentive material, the clay being thoroughly damp. The bank contained about 40,000 cubic yards, including the puddle, practically the whole of which could be obtained as near the bank as it was safe to excavate it. That portion of the bank on the water side of the puddle was entirely composed of good retentive material, the portion on the down side being principally made up of the stripping from the site of the embankment. Otherwise the workmanship

on both sides of the bank was identical. The puddle was kept about 3 inches to 12 inches below the surface of the bank, and no planking being used it was well punned into the sides of its trench.

When paying wages at the rate of 9*s.* per day for navvies, £1 per day for a foreman, 15*s.* per day for a ganger, and £10 per ton for horse-feed, if the average lead did not exceed 8 chains to 10 chains, banking usually cost about 6½*d.* to 7½*d.* per cubic yard, and puddle slightly more.

Work was started about the middle of October, 1897, and was practically finished by the end of January, the reservoir being filled during the ensuing winter. This reservoir has proved of great value to the railway, furnishing, as it does, a practically unlimited supply of good water. The streams feeding it flow for about 4½ months in the year.

Spencer's Brook is the meeting-point of the railway lines from Perth, Albany and the Goldfields; the railway station is about 72 miles from Fremantle. Towards the end of July, 1895, the Author selected a branch of a large creek joining the Avon about a mile above the brook as a suitable site for a reservoir to supply the railway with water: surveys, drawings, and specifications were made, and, after the lapse of some months, tenders were invited; the contract was carried out under the Author's supervision. The reservoir contains 21,000,000 gallons; work was begun in May, 1896, and was finished about the end of March, 1897. The catchment area is 1,200 acres. All the dimensions and slopes of the banks, etc., were the same as already described for Chidlows reservoir, with the exception that 1 foot thickness of metalling, broken to a 4-inch gauge, was placed on the 3 to 1 slope of the bank, and couch grass was planted on the 2 to 1 slope. Gravel was used at Chidlows because of its abundance. On account of the tendency of hand-pitching to become undermined by the wash of the water, broken metal was used for pitching on the water faces of almost all the banks not in contact with running water; in the latter case stone-pitching set in cement-mortar was used. Pitching, of the type described by Mr. W. L. Strange,[1] in his Paper on "Reservoirs with High Earthen Dams in Western India," would, in all probability, meet every requirement; but no opportunity of trying it, or of ascertaining its cost, has occurred. The puddle was almost entirely bottomed on rock, a core-wall being built, as already described. The by-wash rose with a slope of 1 in 50 to the crest, which was

[1] Minutes of Proceedings Inst. C.E., vol. cxxxii. p. 130.

10 feet across, and thence fell with a slope of about 1 in 100 until well clear of the bank, when the water was allowed to find its own channel. The rain being occasionally very heavy, 3 inches sometimes falling in an hour, it was necessary to have large by-washes. The width allowed varied, with the nature and size of the catchment, between 1 foot for every 60 acres for fairly large areas with slow run-off, and 1 foot per 4 acres for small bare-rock catchments where the run-off is exceedingly rapid. Before accepting the tenders for this work it was required that a 3-inch siphon should be substituted for the 3-inch delivery-pipe which it had been intended to take under the bank inside a 24-inch iron pipe with external flanges, set with concrete rings to prevent any creep of water which might pass the flanges of the pipes, the whole to have been laid in puddle in a trench in the solid ground. This siphon proved troublesome even while the railway construction department maintained the reservoir; and after falling into the hands of the maintenance department, the siphons proved unworkable, and a steam-pump has been placed on the main, close to the low side of the bank, which of course involves a heavy annual expense.

A few details of this siphon, its defects and probable cause of failure, may prove useful. The siphon was carried through the bank about 3 feet below high-water level, and down the 2 to 1 slope 2 feet below the surface. The pipes were 3-inch spigot and faucet pipes. The Author believes that the chief faults of this and other siphons constructed in this colony lay (1) in the steep fall of the main down the back of the bank; (2) in the lead joints, which required constant attention to keep them tight; (3) in the high lift, sometimes 19 feet to 20 feet when the water got low; (4) in the temperature of the water, which often reached 70° F. to 80° F. in the summer-time. The water in the reservoir held, dissolved, probably 5 per cent. to 6 per cent. of air and other gases, which, with aqueous vapour, would be partially released at the reduced pressure in the bend of the siphon. Even allowing that only 1 per cent. of gas was given up, every 100 gallons of water that passed through would leave sufficient to fill 1 yard in length of the 3-inch pipe. Owing to the steep fall down the bank, the water would be unable to roll the bubbles, as they formed, down the pipe, where they would have been either re-absorbed or discharged through the air-valves crowning the rises in the pipe below the mean hydraulic grade. To overcome this defect, probably the most serious to which the siphon was subject, a T-piece was inserted in the top, and a 3-inch vertical pipe was added,

containing a long copper float which worked a circular slide-valve above and below, the valves being made circular so that the atmospheric pressure would not affect the friction. When air collected in the vertical tube below the float, it would pass up through the lower valve and collect in the chamber containing the float until, its buoyancy being destroyed by the water sinking to make room for the air, the float would fall, closing the lower valve and opening the upper one, the air bubbling up through, and being replaced by, the water above, which was constantly replenished from a 1,200-gallon iron tank on the bank, kept supplied by a pump which drew from the top of the siphon, thus aiding the automatic air-valve when it was at work. This valve acted well, but it was found that small twigs or other debris not infrequently stopped it; also the tank-full of water only lasted about 8 hours, and when allowed to run dry the siphon would stop. By this means 27,000 gallons were run through the Spencer's Brook siphon and 56,000 gallons through the Northam siphon in 12 hours. The inconvenience thus caused prompted the Author, instead of perfecting the existing system, to recommend the abandonment of the siphons and the substitution of pipes below, or, when the site of the embankment was too rocky, through the lower part of the bank.

Northam is a small agricultural town about 78 miles east of Fremantle, and was until January, 1893, the eastern terminus of the railway; and until the following year the total railway water-supply was pumped from the Burralong pool in the Avon river, between Northam and Spencer's Brook, by means of a hand-pump. About this time the question of a water-supply for Northam was raised, and the townspeople petitioned to be supplied at the same time. Several small schemes of 4 million to 6 million gallons were prepared where the catchments varied between 100 acres and 260 acres. The presence of brine springs restricted the available sites for a dam, and one was chosen having about 120 acres of catchment, on which no salt springs were known. This reservoir is capable of containing 11 million gallons, and in all particulars resembles that at Spencer's Brook. The work was carried out by contract, and was begun in April, 1896, and finished about March, 1897. Fearing that the catchment area would prove too small to meet the demands upon it, the Author applied for and obtained permission to extend and drain the catchment area. The first portion of this work was performed by running a channel westward to drain as much as possible of the railway *land, also a large* one eastward, along the semi-precipitous fall of

the hills towards the Avon. Several portions of this channel were blasted out of the solid rock, besides which many rocks and small precipices had to be avoided and embankments formed. From these channels and the creek beds subsidiary drains were run up every hollow, and smaller ones again fed these, so that the rainfall was conveyed to the reservoir as quickly as possible. The catchment area was increased to 300 acres.

The next reservoir going eastward is the one already mentioned at Cunderdin, 115 miles from Fremantle. The most essential differences between the design of this bank and those previously described were that the bank was 20 feet in width on the top, and that for the sake of economy the width of the puddle was only 3 feet at the top; also, for the same reason, no metalling was placed on the face of the bank. The construction of this tank and that at Merredin was let to the contractor for the railway.

Tammin, situated 130 miles from Fremantle, at the foot of the western slope of the Minkadine range of low hills rising about 500 feet above the adjoining country, was visited by a succession of thunderstorms between 1892 and 1897, some of which almost caused floods. After three such exceptional falls in February and March, 1896, the last one being fairly general throughout the eastern district, the Author recommended the excavation of a large tank, capable of holding 50,000,000 to 60,000,000 gallons, to collect the heavy rainfall and conserve it for dry years. At that time the annual cost of hauling water exceeded the total expenditure on conservation for railway purposes. Permission for a survey was given, and it was made in June and July, 1896, the work being carried out in 1897. The reservoir was constructed by damming a gully at a site 3 miles south-east of the railway station, and the water gravitates from it to the engine tank. The proposal was to immediately conserve 47,000,000 gallons; but just after the work had been started the Author obtained the sanction of the engineer for railway-construction to raise the water-level by 4 feet, thereby increasing the capacity to 94,000,000 gallons on the condition that the original vote should not be exceeded. This was done, although the extra height practically doubled the quantity of material in the bank. The catchment was also enlarged by some hundreds of acres, and the whole drained in a very complete manner. The main drains were excavated by the ordinary methods, the small feeders being made by a plough. In this manner 16 miles to 20 miles of drain, 8 inches wide and 4 inches or 5 inches deep, with the material deposited in a bank on the low side, could be completed in a day. The material to form the bank was obtained within the flooded

area, and, owing to the dry and hard nature of the country, with the exception of the stripping which was ploughed and placed on the low side of the bank, the whole of the excavation to form the bank and puddle had to be blasted out, and then broken up with picks, before being loaded into the drays; while two men with sledge-hammers stood beside the tip man, breaking up and pounding the lumps into the bank.

Another source of expense, at Tammin, was that the foundations for the puddle were carried down 29 feet, for some distance on each side of the creek, and a great deal of it over 16 feet, whereas, according to the trial-shafts, a depth of 4 feet to 5 feet ought to have proved sufficient; but a few small cracks, roots, small soakages, etc., being met with, it was thought wiser to be on the safe side. Two old creek beds filled with sand had also to be cleaned out for the embankment. The following method of preparing the puddle was employed on this work, and was usually adopted by the Author where the circumstances were similar. The clay, which was hard and dry, was blasted down, a number of men broke it up with picks and shovelled it on to a large heap, where a man played a jet of water on it and kept its surface wet. This heap usually contained a supply of puddle sufficient for 1 week to 3 weeks, so that the clay stood soaking, on an average, about 14 days, the stack being added to on one side as it was depleted on the other. Another party of men on the far side of the heap of soaking clay dug it out with narrow spades and threw it forward on to a second heap, from which a third party loaded it into the drays, or tip-waggons, which conveyed it to the trench, into which it was tipped and rammed in thin layers, water being thrown on the rough surface of the previous layer to help the binding.

In all cases more than the authorised work was carried out for the original sum; the storage capacity at Bodallin being increased by 2,000,000 gallons, and the catchment enlarged from 120 acres to 640 acres; and Burracoppin being also enlarged from 75 acres to 1,075 acres, and the whole efficiently drained.

The method of preparing the puddle at Bodallin differed from that described for Tammin. A band of clay several chains in length was stripped and ploughed, and a watercart was driven through it several times; when sufficiently wet it was ploughed and re-ploughed, the horses' feet and the ploughing effecting the mixing. The puddle was then carted to the trench and rammed in the usual way. At both Burracoppin and Bodallin the tanks were deepened to supply material for the bank, and to add to the *depth of the* water.

These three reservoirs were constructed out of one grant of £25,000, all expenses being paid by the authorities, except the professional salaries and the cost of the surveys.

The Merredin reservoir, which is situated on ground with a fall of about 1 in 100, consists of an excavation having an average depth of 16 feet, and measuring 200 feet by 80 feet on the bottom, with 2 to 1 slopes. This excavation was entirely surrounded by a 40-foot berm, and an embankment. The water, which was originally collected off 40 acres of rock, was led into this elevated enclosure along a stone channel aqueduct 2 feet 3 inches in depth, carried on an embankment. The catchment was increased to 60 acres, and finally to 1,250 acres, when the inlet was raised 3 feet 9 inches; but the by-wash, carried through the bank with an original width of 10 feet, was not altered. An iron sluice-gate with balancing weight was suspended over the inlet-channel, and a second, somewhat similar, flood-gate was fixed near by. The first, under ordinary circumstances, is locked open and the other shut, so as to divert all the water from the race to the tank when desirable, but this could be reversed by the caretaker in a few seconds.

The tanks from Parker's Road to Bulla Bulling are practically the same as Merredin, despite the configuration of the ground, the design being considered successful in minimising evaporation.

The Author will conclude by describing a few defects which showed themselves from time to time.

When excavating the tank at Kellerberrin, the contractor put the puddle on the 1 to 1 batter, and when completing the tank the Author had it covered with broken metal, to protect it from the sun and the wash of the water. It was subsequently found that the puddle had not been carried down to an impervious foundation, the ground around the tank becoming so soft that a horse could not walk on it, and a stream of water flowing from the lowest portion of the bank. To stop this the Author sank a trench through the bank along its entire length, bottoming it on the granite most of the way, the rest being in a hard argillaceous rock. This trench was started at one end and carried right through in short lengths, on account of the water, and was filled up with excellent puddle. The timber was withdrawn as the puddle was filled in. The success of this procedure was proved by an old well in the gully below the tank drying up.

Particulars of the actual quantity of water collected from measured falls of rain are given in the Appendix, Table III.

[Appendix.

APPENDIX.

TABLE I.—RAINFALL AT NORTHAM (1877–1899), SOUTHERN CROSS (1880–1893), IN INCHES.

—	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
1877 Northam	..	..	..	1·30	5·50	0·50	4·20	1·90	0·50	..	..	..	13·90
1878 „	..	0 50	1·10	0·90	0·60	1·90	5·10	3 10	0·90	..	0·20	..	14.30
1879 „	0·70	..	0·10	0·10	3·50	0·40	2·00	0·70	0·40	0·20	..	0·20	8·30
No record from 1880–1883	—	—	—	—	—	—	—	—	—	—	—	—	—
1884 Northam	..	0·22	..	0·16	2·05	6·94	0·78	4·34	1·13	1·15	0·20	..	16·97
1885 „	0·11	0·23	0·49	0·79	5·28	3·29	3·61	2·75	1·25	0·51	0·49	0·50	19·30
1886 „	0·01	1·09	0·20	0·38	0·89	1·40	3·13	5·22	2·55	0·16	0·69	..	15·72
1887 „	0·03	0·9	0·53	1·23	1·82	3·01	3·40	3·65	1·58	0·62	0·59	0·17	16·72
1888 „	1·70	0·74	0·05	1·20	1·98	3·30	1·44	2·76	1·28	0·74	0·88	1·37	17·74
1889 „	0·42	..	..	2·70	1·47	4·12	1·30	2·13	1·84	3·95	0·28	..	18·21
„ Southern Cross	0·59	0 04	..	0·46	2·24	2·27	1·70	0·88	1·01	0·59	0·39	..	10·17
1890 Northam	..	1·05	..	0·05	2·68	4·59	2·17	3·22	2·70	3·60	0·05	0·62	20·73
„ Southern Cross	—	—	—	—	—	0·35	1·21	0·73	0·88	0·92	0·53	0·25	—
1891 Northam	..	..	0·87	..	2·01	4·05	3·56	1·09	1·31	0·07	..	0·14	13·10
„ Southern Cross	..	..	0·21	0·03	1·45	1·35	1·00	0·22	0·50	0·24	..	0 23	5·23
1892 Northam	0·01	..	0·83	2·62	1·68	1·26	3·61	3·22	0·78	0·07	0·34	..	14·42
„ Southern Cross	0·62	0·04	4·17	0·86	2·06	0·41	2·52	1·79	0 79	1·19	0·25	0·40	15·10
1893 Northam	0·35	0·39	0·20	1·88	2·93	2·63	5·26	2·20	3·17	0·58	0·40	0·15	20·14
„ Southern Cross	0·71	0·19	1·28	1·42	3·47	1·44	1·59	0·83	0·70	0·16	0·48	1·77	14·04
1894 Northam	..	0·13	0·94	..	1·08	2·41	2·17	1·92	2·33	0·23	0·58	..	11·79
„ Southern Cross	0·63	0·18	1·08	0·04	0·37	0·46	0·80	0·69	0·42	0·05	0·19	0·21	5·12
„ Mooranoppin	—	—	—	—	—	—	—	1·03	0·65	0·13	0·05	0·23	—
1895 Northam	0·07	0·22	0·05	0·37	0·72	4·97	3·54	4·80	2·26	0·44	..	0·11	17·55
„ Southern Cross	0·04	0·10	0·02	0·17	0·81	1·68	0·61	1·55	0·42	0·02	..	..	5·42
„ Mooranoppin	0·27	0·27	..	0·23	0·30	2·56	1·79	2·88	0·95	0·15	0·17	0 03	9·60
1896 Northam	..	0·15	4·88	0·28	0·82	3·27	6·86	1·23	0·37	0·37	0·02	0·47	18·72
„ Southern Cross	0·73	0·19	3·16	..	0·28	0·66	2·25	0·55	0·14	0·15	0·89	1·78	10·78
„ Mooranoppin	0·85	0·27	4·37	0·32	0·42	2·76	2·91	1·21	0·12	0·56	0·18	1·56	15·53

.. Signifies "No rain." — Signifies "No record."

TABLE II.—RAINFALL AT MOORANOPPIN PREVIOUS TO 1893.

Year.	Inches.	Year.	Inches.
1888	13·64	1891	8·41
1889	12·48	1892	17·38
1890	13·34		

TABLE III.—RAINFALL IN THE NORTHAM–MENZIES DISTRICT.

Place.	Rainfall.	Duration.	Quantity Conserved.
Week ending 5 October, 1899.			
	Inches.	Hours.	Gallons.
Bulla Bulling	0·15	10	Nil.
Boorabin	0·06	17	,,
Karalee	0·07	20	,,
Koorarawalyee	0·28	20	,,
Yellowdine	0·32	85	92,000
Southern Cross	0·25	..	Nil.
Parker's Road	0·34	Light shower	,,
Bodallin	0·26	,,	42,000
Burracoppin	0·24	,,	Nil.
Merredin	0·44	,,	295,000
Kellerberrin	0.34	,,	60,000
Tammin	0·55	22	144,000
Cunderdin	0·70	7	433,000
Week ending 12 October, 1899.			
Parker's Road	0·20	2	Nil.
Bodallin	Nil	Nil	,,
Kellerberrin	0·21	Light shower	30,000
Tammin	0·54	27	Nil.
Cunderdin	0·45	13	54,000
Week ending 19 October, 1899.			
Woolgangie	0·05	25	15,600
Karalee	0·20	37	261,000
Yellowdine	0·17	20	33,000
Bodallin	0·07	2	Nil.
Tammin	0·04	30	,,
Cunderdin	0·24	4	,,
Week ending 26 October, 1899.			
Kellerberrin	0·23	3	120,000
Tammin	0·29	3	Nil.
Cunderdin	0·21	3½	54,000
Week ending 2 November, 1899.			
Bardoc	..	..	2,045,000
Bulla Bulling	1·33	3	1,061,675
Woolgangie	0·95	3	2,611,600
Boondi	0.95	3	1,076,000
Boorabin	0·93	3	934,467
Karalee	1·00	3	1,084,600
Yellowdine	0·93	3	293,000
Koorarawalyee	1·20	3	97,300
Southern Cross	1·24	..	300,000
Parker's Road	0·49	2	290,000
Burracoppin	0.80	4	1,700,000
Merredin	0·82	3½	2,660,000
Kellerberrin	1·02	4	200,000
Tammin	1·45	5	5,300,000
Cunderdin	0·97	4½	1,000,000
Northam	..	2½	1,000,000

(*Paper No. 3293.*)

"Note on the Working of Sand Filters."

By HENRY FILLMER RUTTER, M. Inst. C.E.

THE object of the following communication is to draw attention to a practical improvement in the working of slow sand filters, which has resulted in greater economy and convenience, and virtual increase of the capacity of existing plant.

The designation "slow sand filters" is used to distinguish sand filters of comparatively large area, operated by gravitation, from those sand filters of comparatively small area in which mechanical means of agitation and reversal of the current for the purpose of cleaning are made use of. The latter class may be subdivided into two types—namely, that in which the water is passed through the filter by gravity alone, and that in which additional pressure is used to accelerate the flow. With these two types of filter coagulants are usually employed. Although filters of the latter class are in use to a considerable extent—especially in America, where, in the Northern States, the climatic conditions are too rigorous to permit of the convenient working of exposed filters—yet by far the greater quantity of water filtered through sand is treated in open beds of large size.

A few years ago it was believed that the function of the sand in filters was quite a secondary one—that the sand was merely a porous structure convenient for upholding the surface film, on which the efficiency of the filter actually depends. It was stated that the formation of this film on the surface of the sand should be promoted by subsidence after each cleaning of the filter; that the subsidence should be prolonged for several hours before the filter was again set to work; that the integrity of the film should be maintained with the greatest care; and that its rupture would be followed by immediate deterioration of the filtrate from a bacterioscopic point of view. In the practical working of open filters the maintenance of the surface film is impossible. In the summer months the gases generated among the low forms of vegetable life which grow on the surface of the sand float these matted growths to the surface of the water, thus frequently

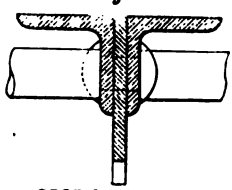
exposing clean patches of sand to the passage of the water. In the case of mechanical filters the supposed necessity for maintaining the integrity of the surface film is frankly ignored. At frequent intervals between the periodical cleansings by reversal of the flow, revolving arms drag short lengths of chain over the surface of the sand, with the express purpose of rupturing the film and so permitting the passage of the water with greater freedom.

Among other observers who were dissatisfied with the surface-film theory, Mr. Clark, Chief Chemist to the Massachusetts Board of Health, carried out a series of tests at the experimental filter station at Lawrence, Mass., the results of which were kindly communicated by Mr. Clark to the Author when he visited the station in 1899. These results seemed to prove conclusively that rupture of the film has no prejudicial effect on the filtrate. On his return to England the Author ventured to suggest the systematic disturbance of the surface film in the working of a large plant of open filters, having a capacity of 25 million gallons per day, with which he is connected. This filter plant deals with river water of fair initial purity, which can, as a rule, be filtered quite easily, giving a filtrate of excellent bacterial character. In the spring of every year, however, and in some years throughout the summer months, inconvenience in the working of the filters is caused by the rapid clogging of the surface of the sand by the formation of a film, which, although of extreme tenuity, is sufficient to prevent entirely the passage of water. Filters which at other times may continue to filter efficiently for 2 months or even 3 months without the necessity of cleaning them by the removal of the surface of the sand will, at the seasons mentioned, frequently be rendered entirely useless after only 5 days' or 6 days' work. The inconvenience caused by this behaviour of the filters at the season of maximum demand is great, involving, as it must, the laying-off of the filters for cleaning at very frequent intervals, with the consequent reduction of available area and the heavy expense of washing and re-spreading considerable quantities of sand. The disturbance of the surface film by the simple means to be described later has, during the last 18 months, resulted in greatly increased facility of working and material reduction of expense, while the high character of the filtrate has been fully maintained.

Immediately the filter shows signs of clogging, by reduction in the rate of flow, the outlet of the filter is closed, and an interval of about 6 hours is allowed to elapse before the film is disturbed,

in order to ensure that the whole body of sand below the film shall be fully charged with water. After the disturbance of the surface the filter is again allowed to stand idle for a period of 6 hours. The latter precaution is found in practice materially to increase the further life of the filter. The result of disturbance of the surface is often curious. A filter which shows signs of blocking up within 5 days or 6 days after cleaning will, after treatment, frequently work for 3 weeks or 4 weeks before requiring further disturbance, although the character of the water supplied to it may remain identical. In the case of the filters under consideration, it is found that disturbance can be effected two or three times before cleaning becomes necessary.

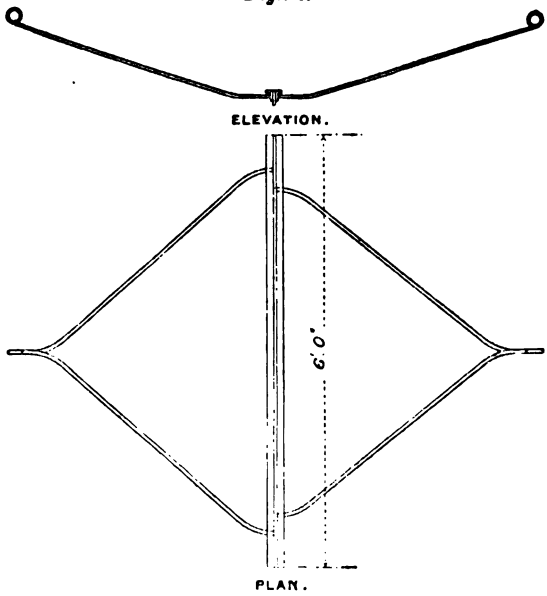
Fig. 1.



SECTION OF DRAG.
Scale, 6 inches = 1 foot.

The apparatus used consists of a broad rake composed of a thin strip of iron riveted between two light angle-bars, *Fig. 1.* The

Figs. 2.



Scale, $\frac{3}{8}$ inch = 1 foot.

lower edge of the strip is slightly serrated to prevent the rake *from slipping* over the surface of the film without breaking it up. *On each side* is a handle of $\frac{1}{2}$-inch round iron (Figs. 2), to which

a light rope is attached, of a length somewhat greater than the width of the filter. The weight of the rake in air is 40 lbs. The rake is pulled backwards and forwards across the filter by two men, and is shifted laterally a distance equal to its own width each time it reaches the retaining wall.

The Author is aware that similar methods have been in use for many years in some filter plants, but he finds that in many installations the advantages of disturbance of the film are unknown, and in cases where that treatment has been adopted it has neither been carried out systematically, nor with the precautions which he suggests.

The Paper is accompanied by a tracing, from which the Figures in the text have been prepared.

(Students' Paper No. 451.)

"The Sewerage and Sewage Disposal of Burton-upon-Trent."[1]

By JONAH WALKER SMITH, Stud. Inst. C.E.

THE Borough of Burton-upon-Trent comprises an area of 4,025 acres, and has a population of 51,000. That part of the borough which lies to the east of the River Trent, having an area of 1,375 acres and a population of 11,000, is entirely residential, and has not at present a water-carriage system of sewerage. The remaining area of 2,650 acres on the western side of the river (*Fig. 1*) is exceedingly flat, rendering works of drainage somewhat difficult, especially as the level of the subsoil-water was originally only 4 feet or 5 feet below the surface. In the following Paper the Author presents a description of the work which has been carried out since 1883.

Old System of Sewerage.—Prior to that time, the sewerage of the town was very defective. The outfall was near the site of the present pumping and liming station. The daily dry-weather flow was 4,000,000 gallons, from a population of 30,000. The whole of this passed rapidly through inefficient settling-tanks, after receiving a varying quantity of lime, for the application of which there was no mechanical apparatus. The sewage, being partially clarified in its flow through the tanks, found its way into the River Trent. The results of this treatment were soon apparent. The effluent polluted the river to a distance of several miles before oxidation was completed; there were gross deposits on the banks, and a growth of succulent flannel-weed and sewage-fungus in the bed. The sludge deposited in the tanks, when withdrawn, was laid on the side of the banks, and either washed into the river by floods or dried by the atmosphere; considering that there was 90 per cent. of water in the sludge, it will be readily understood that the stench from this drying process was felt for some distance.

The daily dry-weather flow of sewage, 130 gallons per head,

[1] This Paper was read and discussed at a Meeting of the Birmingham Association of Students of the Institution on the 7th December 1899.

was exceedingly high and caused special difficulty from a financial point of view. It was accounted for by the following circumstances, viz. :—

(1) There were several natural streams forming the main sewers of the town, which at one time were open water-courses, but, having been polluted with sewage, had been covered over as nuisance arose, or building operations extended, and had come to be recognized as public sewers.

(2) The outfall-sewer was leaky and defective, and was constructed for some length below the saturation-level.

Fig. 1.



Scale, 1 inch = 50 chains.

PLAN OF DRAINAGE-AREA, SHOWING INTERCEPTING SEWERS.

(3) A very considerable amount of waste-water from the brewery operations in the town was discharged into the sewers.

The first and second of these causes have now been removed, but the third still remains, and constitutes a most important item in the sewage-disposal of Burton. It is shown by statistics that Burton produces about 4,000,000 barrels of beer per annum, and water is required not only for the actual brewing, but also for boiler use, for washing out plant and casks, for general cleansing, for cooling purposes both in the refrigerators and through the attem-

perators, and for many other purposes. It may be considered that for each barrel of beer produced, twelve and one-half barrels of water are required. It will thus be found that 50,000,000 barrels, or 1,800,000,000 gallons, of water are used yearly; this altogether dwarfs the 400 million or 500 million gallons used yearly for domestic purposes.

The sewers then in use were much in excess of the possible requirements; this, together with very flat gradients, formed a grave defect. In general, the main sewers were culverted brook courses, with irregularities in line, inclination, area of cross-section and construction; the subsidiary sewers were either of 4½-inch brickwork or of half-socketed earthenware pipes. In some cases the sewers were silted up to three-fourths of their height in foul, putrifying matter, which, on account of its peculiar character, readily gave off sulphuretted hydrogen in such quantities as to render it dangerous for men to work in them. This silting up of the sewers was caused not only by their being of large capacity and flat gradient, but by being backwatered by the river when in a state of flood. During the months of October, November, and December, 1891, the sewers were backwatered on 33 days. This is the more serious when it is considered that the backwatering was constant for periods of 11 days and 18 days. On account of the exceedingly flat gradients, practically the whole of the old sewerage system was affected, and on 7 days the main outfall was subjected to a slight internal pressure. The effect of this backwatering is apparent. The solid matter in the sewage, together with the solid matter in the flood-water, would be precipitated during the state of quiescence, and would help towards the effectual silting up of the whole sewerage system.

In 1884 it was decided, on account of the pollution of the river at the tanks, to erect a pumping-station there, and to pump the whole of the sewage to a farm, and there treat it by broad irrigation and intermittent filtration. A suitable tract of land, 566 acres in extent, with a gravel and loam subsoil, was found at a distance of 3 miles from the pumping-station; the net area for sewage treatment was 362 acres, the remainder for various reasons not being available for this purpose. The 362 acres were underdrained with 6-inch and 4-inch drain-tiles, laid at a depth of 6 feet, 1 chain apart; the effluent was discharged into the River Trent at Willington by a 30-inch brick conduit, 1 mile in length. Since the original laying-out of the farm, further additions have been made to it, until at the present time there are 713 acres, of which 515 acres are available for sewage treatment, the remainder being in grass, and occupied by buildings, roads, etc. Houses and

cottages have been erected and are occupied by the farm manager, foremen and labourers. The sewage is delivered on to the farm, from the pumping-station, by a 27-inch cast-iron rising-main, which enters the farm from the south-east; the main is provided with stand-pipes at a sufficient elevation to control the whole farm. From the rising-main the sewage is delivered on to the surface at various points, from sluices, at which outlet-chambers are built; and distributing-pipes convey the sewage over the land. When the farm was first used, no chemical treatment of the sewage was employed, irrigation and filtration through the land being relied upon entirely for purification.

An artesian well for the supply of water to the farm buildings has been sunk through the upper Keuper beds of gypseous marl, alternating red and yellow sandstones and one or two thin layers of marl, and is now 360 feet in depth; it is expected to strike the Bunter conglomerate at a depth of 370 feet. A private well was sunk about a mile from this spot, and from the Bunter bed a copious supply of moderately hard water at a temperature of 55° F. was obtained.

Pumping Station.—There are two engine-houses, each of which accommodates two engines, fitted with every convenience to facilitate the work. These four engines are of the compound condensing beam-type, with parallel motions, each having two ram force-pumps, one placed under the high-pressure cylinder and the other at an equal distance from the other end of the beam. Each engine is capable of lifting 130,000 gallons per hour to a height of 110 feet at a speed of 12 revolutions per minute. The high-pressure cylinders are 24 inches in diameter, and have a piston stroke of 6 feet; the low-pressure cylinders are 38 inches in diameter, with a piston stroke of 8 feet, and were tested with water to a pressure of 100 lbs. per square inch. The fly-wheels are 24 feet in diameter and each weighs 24 tons. Each engine is provided with a condenser and a 24-inch air-pump. In each house there is a 10-ton travelling crane, operated by manual labour, with gearing so arranged that three men can easily raise 10 tons. Each engine is fitted with a counter, in sight of the driver, so that the speed can be easily regulated; pneumatic tubes connect the two engine-houses with the boiler-house and also with the liming department, mentioned later, whilst indicators placed in a convenient position show the level of the sewage in the suction-culvert at any moment.

The eight pumps are of the plunger type, each 21 inches in diameter, and 6 feet stroke. The barrels are of cast-iron, 4 inches larger in internal diameter than the rams, which are also of cast-

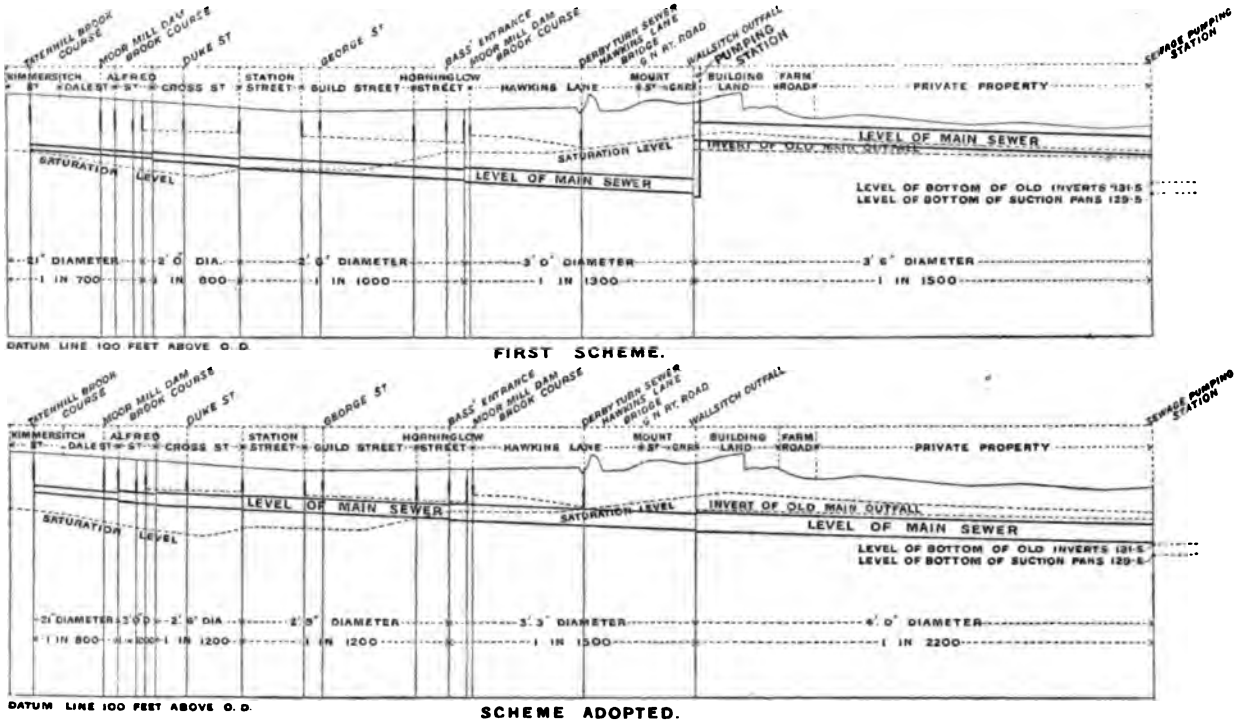
iron. Each pair of pumps has a suction-pipe, 24 inches in diameter, connected directly to the suction-culvert at a distance of 90 feet, and with a lift of about 11 feet, and delivers into a 24-inch rising-main fitted with a reflux-valve. These four 24-inch rising-mains are each fitted with an air-vessel having a capacity of 170 cubic feet, and are united into a 27-inch rising-main which conveys the sewage to the farm, a distance of 3 miles.

There are five boilers, each 7 feet in diameter and 30 feet in length, with two flues, each 2 feet 9 inches in diameter and containing five water-tubes. The working steam-pressure is 80 lbs. per square inch, and the loss of pressure between the boiler and the high-pressure cylinder is only 2 lbs. per square inch. The boiler feed-water is derived from a spring on the site, and is pumped into two tanks, each having a capacity of 10,000 gallons, and in these tanks is treated by the lime and soda-ash process of softening. Thence it gravitates to the feed-pumps, passing on its way through a system of coils under the lime-slaking floors, the effect of which is to raise the temperature from about 60° F. to 150° F., resulting in a considerable saving of fuel. There is at present a fitting-shop with appliances for executing all except the largest repairs, but this is about to be enlarged and fitted with the most modern machinery, capable of dealing with any repairs likely to be required. A scheme is now in hand for the electric lighting of the works; for this purpose an engine of 14 brake-HP. will be provided, together with the electrical plant necessary for supplying about one hundred and fifty 16-candle-power lamps, at an estimated cost of £700.

New Main Outfall and Intercepting Sewers.—Two schemes were proposed for a system of sewers between the town and the pumping-station. In considering these schemes, it should be remembered that the pumps had been completed and fixed, and that the suction-pans were placed at a level 7 feet lower than the invert of the old outfall-sewer at the pumping-station.

In the first scheme, it was proposed to lay a new main outfall-sewer 3 feet 6 inches in diameter, with a gradient of 1 in 1,500, between the pumping-station and Wallsitch (*Figs.* 2), where the invert would have been 2·40 feet above that of the existing culvert. The main intercepting sewers from this point would start at a level of 4·25 feet below the invert-level of the old outfall-sewer; this, of course, would have necessitated an additional pumping-station at this point, capable of lifting the whole of the sewage to a height of 10 feet or 11 feet. Had this scheme been adopted, the minimum depth below the existing main sewer at the head of the system would have been increased by 4 feet, and

Figs. 2.



Horizontal Scale, 1 inch = 2,500 feet. Vertical Scale, 1 inch = 40 feet.

thus, while providing for self-cleansing gradients with a minimum velocity of 150 feet per minute, free outlets would have been given to the existing subsidiary sewers which might be found in good condition, and the drainage of the whole of the area within the borough boundary would have been accomplished. It was thought, however, that the deep sewer would seriously affect the yield of the brewers' wells. This was, of course, a point worthy of serious consideration, and to investigate the matter the levels of the water in forty-three wells were taken, on a Sunday, when the water would be at its highest on account of the brewery pumps not being at work, and borings were made to arrive at the geological strata. From the information thus obtained it was found that the natural water-bearing stratum was approximately parallel to the surface, and followed the direction of the flow of the river; but by continual pumping the water-level had been altered, and the water flowed from all directions towards the centre of the town. It was also found to vary considerably in a short space, and did not rapidly adjust its level. The saturation-level, as found and plotted (*Figs. 2*), shows this deep sewer to be considerably below it, and it was thought that this trench would intercept the water from the town, and carry it down the valley. The scheme was rejected in favour of the modified scheme which has been carried out.

This scheme provided for improvements at the pumping-station by constructing a tank-sewer, 9 feet by 8 feet, outside the main building, lengthening the 21-inch suction-pipes to it and removing the old tanks directly under the engine-houses; these tanks, being very large, caused much nuisance in the building through the secretion and subsequent putrefaction of sludge spread over a somewhat large area. A screen-house was also erected to separate the coarser matters, such as paper, corks, wood, etc., and anything likely to clog the pump-valves or any part of the machinery. From the tank-sewer, a main outfall-sewer, 4 feet in diameter, was constructed to the Wallsitch, with a gradient of 1 in 2,200. The level at this point will admit of the drainage by gravitation of nearly the whole area of the borough, including that part on the eastern side of the river. From about this point, main sewers branch out into three zones, into which the borough is divided for drainage purposes. It will be seen from the section (*Figs. 2*) that the main outfall-sewer is above the saturation-level until it reaches a point near the Wallsitch. There is, however, no fear of the water escaping from the town, as the sewer is perfectly watertight; it is built of two courses of brick in cement with a

rendering of cement between the courses, and surrounded with concrete 6 inches in thickness.

The scheme adopted has practically all the advantages of the first scheme proposed, and few of its disadvantages. The sewers have a minimum velocity of 130 feet per minute, which renders them self-cleansing, and, being 1 foot below the level of the existing sewer at the head of the system, the old subsidiary sewers, which have been found to be in good condition, are connected up and benefit by the free outlet afforded. The auxiliary pumping-station at Wallsitch, with its continuous expense, has been avoided now that the system is one of gravitation to the main pumping-station; and the fear of loss of subsoil-water is reduced to a minimum. The object of this scheme is to accelerate the flow of sewage to the pumping-station and to get it on to the farm in a fresh condition, and not in the advanced state of putrefaction which resulted from the old and sluggish sewers; and, further, by cleaning out many of the old sewers and connecting to them the gullies, hot- and cold-water pipes, and rain-water pipes, to separate this water, restore the brook courses to their natural condition, and allow them to discharge direct into the river, thus minimising the cost of pumping and treatment. All the sewers of a greater diameter than 1 foot 9 inches are of brick in cement, the inside ring being of blue Staffordshire bricks and the outside ring of common red bricks; those of 1 foot 9 inches in diameter or less are of ordinary stoneware pipes, except where water has been met with, when Hassal pipes have been employed, or the pipes have been surrounded with concrete. Manholes of a greater depth than 15 feet are of circular brickwork, 4 feet in diameter, and those of less depth than 15 feet are rectangular, measuring 4 feet 9 inches by 3 feet 2 inches. The house-connections have been provided with disconnecting-traps and inspection-chambers. Ventilation is provided by air-inlets with mica flap-valves in front of the houses, and by outlet-shafts at the rear. With regard to flushing arrangements for the mains, the sewers are generally effectually flushed by the sudden and intermittent discharges of sewage incidental to brewery operations; but special arrangements have been made for this purpose at the several points where the sewer crosses the old culverted brook-courses, by inserting a trumpet-mouthed pipe into the invert of the old culvert and connecting it to a valve-chamber on the line of the new sewer. On account of the exceedingly foul nature of the sewage and the rapid evolution of foul gases and steam, open ventilation in the town is out of the question. A few ventilating shafts have, however, been carried up and connected to factory chimneys; these have been found very successful, but

the ventilation by this means is only local, and owners are sometimes unwilling to allow their shafts to be used for this purpose.

The foregoing is a description of the sewerage works in the main portion of the borough, lying on the west side of the river, and these works are just approaching completion.

The area on the eastern side of the river, comprising 1,375 acres with a population of 11,000, has at present no complete water-carriage system, but a scheme has just been completed and detail drawings are being prepared.

The amount of sewage proper has been reckoned as 25 gallons per head per day. The Local Government Board requires provision to be made for the dilution of this with five times its quantity of rain-water before it is allowed to overflow into the river, and this basis has been adopted for calculating the sizes and arranging the overflows. The Author would suggest that instead of an arbitrary rule being laid down for all cases irrespective of the particular character of the sewage, chemical analyses be made, and albuminoid ammonia be taken as the standard of impurity, such dilution being provided for as would reduce the albuminoid ammonia to 0·15 per 100,000 before the overflow would come into operation. In this way weak and highly concentrated sewages would be dealt with on their merits.

The most careful and skilful attempts to produce artificially a water similar to the Burton supply have proved unsuccessful, at least in obtaining a water equally suitable for brewing beer. On an average 5,000,000 gallons of water are daily dealt with through the sewers, and of this about 1,000,000 gallons are supplied by the South Staffordshire Waterworks Company, and the remainder is derived principally from deep borings and shallow wells. The South Staffordshire water is a fairly high quality drinking-water, with a strong tendency to permanent hardness, containing very little chlorine and mere traces of nitrates, while the amount of free and albuminoid ammonia is very small. It is a spring-water, obtained from tubes in gravel beds at Fradley, and is conspicuously free from organic contamination. The character of the well-water is, however, of most importance. From the following Table of analyses it will be seen that the deep wells yield a permanently hard water, strong in chlorine, with practically no nitrates, and a mere trace of free and albuminoid ammonia, while the shallow wells and tubes, 20 feet to 32 feet in depth, give a permanently hard water containing a high percentage of sulphates and chlorine, with 1·6 per 100,000 of nitrates and nitrites.

Of the more important impurities in these waters, carbonates of lime and magnesia are dissolved by the rain-water in passing

through the gravel, marl, and sandstone, which contain it in varying quantities; sulphates of lime and magnesia are taken up in its passage through the beds of gypsum; nitrates, so high in the shallow wells, are accounted for by surface pollution, the soil in a populous neighbourhood becoming more or less saturated with foul water; the nitrogenous matter and organic ammonia, resulting from the saturation, have been oxydised first into nitrous acid and then into nitric acid, combining with bases to

ANALYSES OF BURTON WATERS.[1]

(Estimation in parts per 100,000.)

—	Shallow Wells and Tubes 20 Feet to 32 Feet in Depth.	Marl Beds, Upper Keuper, 70 Feet to 200 Feet in Depth.	Sandstone Beds, Lower Keuper, 350 Feet to 525 Feet in Depth.	Conglomerate (Bunter) 180 Feet to 400 Feet in Depth North East of the Town.
Carbonate of lime . . .	20·0	20·0	18·0	16·0
Carbonate of magnesia . .	5·0	3·0	4·0	9·0
Sulphate of lime . . .	45·0	147·0	87·0	14·0
Sulphate of magnesia . .	17·0	32·0	18·0	..
Sulphate of soda . . .	..	1·0	24·0	10·0
Nitrate of magnesia . . .	9·0	4·0	..	..
Nitrate of soda	..	1·0	..	..
Chloride of magnesium . .	2·0	1·0	..	..
Chlorides of sodium and potassium	12·0	10·0	41·0	19·0
Difference—silica, alumina, iron, etc.	1·0	1·0	2·0	..
Total solids dried at 360° F.	111·0	220·0	194·0	68·0
Free ammonia	0·006	0·003	0·028	0·025
Albuminoid ammonia . .	0·008	0·004	0·004	0·005
Chlorides expressed as chlorine	8·5	6·5	25·0	11·4
Nitrates expressed as nitrogen	1·6	0·8	Trace	None

form nitrites and nitrates of those particular bases. Chlorine is not in this case a sure sign of organic pollution. A brine-spring exists in a bed of marl which outcrops at Branstone, 1½ mile from Burton, and water from this district has been found to contain as much as 940 per 100,000 of chlorine, or 1,085 grains of common salt per gallon.

The sewage of Burton is unique in character, of a most offensive nature, and very difficult to deal with. Briefly, the difficulty is caused through the peculiar character of the waste waters from breweries, which contain considerable quantities of polluting

[1] These analyses are from records by Messrs. Matthews and Lott of Burton.

matter in the shape of spent hops, seeds, dead yeast, and other organic vegetable matter. The abnormally high temperature of the waste-water from breweries, often discharged into the sewers at a temperature of about 180° F., assists the rapid fermentation and decomposition of the sewage.

Lime Treatment.—The treatment may be briefly described thus:—To the raw sewage, on arrival at the pumping-station, lime is added to the extent of 40 grains of caustic lime per gallon; the limed sewage is agitated by a revolving wheel, which operates along the whole length of the tank sewer, and is then pumped on to the farm, a distance of 3 miles, and filtered through the land. It has been found that an excess of lime is absolutely necessary to prevent smell on the surface of the farm. The smell is caused by the evolution of sulphuretted hydrogen, due to the action of organic acids on the sulphides in the sewage. Lime treatment prevents aerial pollution, and transfers the seat of decomposition to the soil. The amount of lime to be applied varies with the flow and with the character of the sewage, which are very irregular. To meet this difficulty of irregularity, a test-office has been erected at a point on the main outfall-sewer, a short distance below the confluence of the subsidiary main sewers near the Wallsitch. The sewage is tested for sulphuretted hydrogen every ¼ hour, day and night, by taking a gallon of sewage in a stoppered bottle, and adding 40 grains of caustic lime. This is thoroughly shaken, and allowed to stand for 5 minutes. An acetate of lead paper is then suspended in the bottle for 5 minutes; if the paper is not discoloured, the sewage is considered to be normal, and is treated to 40 grains per gallon in the ordinary way; if, however, the paper is discoloured, more lime is added until the paper ceases to be discoloured, and the number of grains per gallon necessary to effect this is telephoned to the pumping-station, where lime is added accordingly. To check the accuracy of these tests, similar tests are made at the pumping-station from the suction-culvert, after the lime has been added and thoroughly mixed with the sewage by the agitator. Finally, similar tests are made hourly with the sewage when delivered on to the farm. Samples of effluent are taken periodically and submitted to analysis. It will thus be seen that much depends upon the effectual liming of the sewage at the pumping-station.

An alternative scheme to establish the liming-works at the farm was proposed, but the pumping-station site was considered preferable, its advantages being:—

1. An efficient staff was already on the spot, and the same management controls both the pumping-station and the liming-works.

2. The prime cost of the works, sidings, etc., was greatly in favour of the pumping-station site.

3. The existing boiler-power can be utilized.

4. The works are sufficiently near for the workmen to reside in Burton.

The disadvantages of the site adopted are:—

1. The rising-main has become coated with lime for some distance, and when it is considered that a coating of only $\frac{1}{4}$ inch in depth contracts the water-way 3·7 per cent., the effect of this becomes apparent. This coating causes additional friction, and more power is therefore required.

2. Sluices and air-valves on the rising-main become difficult to work on account of lime adhering to them.

3. Clacks become coated with lime, which interferes with their efficient working, and thereby increases the amount of slip in the pumps.

In dealing with so large a quantity of lime annually, viz., upwards of 5,000 tons, economy of manipulation is of the greatest importance. The cost of lime, including that of labour employed in its application, amounts to over £4,000 a year. It has been proved that lime introduced in a very finely divided state and thoroughly incorporated with the sewage acts more quickly, giving a much better result than when added in a coarser state. Derbyshire lime is used, guaranteed 90 per cent. caustic, and at present is slaked, allowed to cool (which is found to be necessary), mixed with raw sewage-water, and added to the sewage as milk of lime, the whole being thoroughly incorporated by the agitator in the tank-sewer already described. The lime process was started in 1893 upon the advice of Professor Dewar; at that time the Corporation was under an injunction, and the works having therefore been hurriedly constructed are essentially of a temporary character. A scheme for permanent works is now in hand.

On account of the rapid variations in the character and flow of the Burton sewage, there is some difficulty in getting a correct expression of its average composition in the raw state. Experiments have been made in order to obtain this, and also to ascertain the result of the lime treatment with regard to the resultant sludge. Complete tests were made daily for a period of 20 days in the following manner:—Samples of raw and of limed sewage of 1 gallon each were taken every $\frac{1}{2}$ hour throughout the 24 hours. These were bulked and analysed, and the average of the twenty analyses was the following:—

RAW SEWAGE.

(Expressed in parts per 100,000.)

Total Solids.	Loss on Ignition.	Oxygen Absorbed in 4 Hours.	Free or Saline Ammonia.	Albuminoid Ammonia.	Chlorine.	Nitrites.	Nitrates.	Phosphates.	Alkalinity as Carbonate of Lime.
190·75	76·75	10·18	1·89	1·91	12·6	None	None	Quantity	10·0

The supernatant water from the limed sewage was drawn off and the resultant sludges were analysed.

SLUDGES.

Sludge per cent. of Original Sewage by Volume.	Dry Matter per cent. of the Sludge.	Ash per cent. of the Dry Matter.	Sludge in Tons per 1,000,000 Gallons.	Grains per Gallon of Caustic Lime used as Precipitate.
2·87	4·75	55·7	128·32	50
1·78	5·35	54·1	79·41	30

The solid matter in the sludge is small and below the average, which is 10 per cent. Sludge obtained by precipitation without lime yields 10·7 tons per 1,000,000 gallons, of which 10 per cent. are solids. The sludge obtained by the lime precipitation experiments was placed in a small earth pit and parted with its superfluous water rapidly, and there was no smell from it after lying for some time.

The chief difficulties encountered at the sewage farm may be classified thus:—

1. Danger of foul smells arising when sewage is being delivered on to the farm, whilst on the surface, and from ventilating pipes and manholes.
2. The tendency for the ground to become sewage-logged.
3. Difficulties of cropping and general management of filter-beds.
4. Black deposit in subsoil-drains and growth of sewage-fungus in the river.

It has already been mentioned that the rapid evolution of foul gases, particularly sulphuretted hydrogen, is one of the peculiarities of Burton sewage. So bad was this in 1892, before the application of lime, that an action was brought against the Corporation and substantial damages obtained by a person who *experienced* a nuisance 5 miles away from the farm; it was in

consequence of this injunction that immediate steps were taken to check the pollution of the atmosphere.

The sulphur in the sewage occurs in the following forms, viz. :— (1) In a natural state ; (2) In organic combination with hops yeast, and malt ; (3) As sulphides, resulting from the splitting up of sulphates in the water ; (4) As sulphurous acid, used by the brewers in washing out vessels.

The added lime fixes the sulphur and effectually prevents this serious aerial pollution. At one time somewhat offensive gases, produced by decomposition below the surface, were given off from the ventilating-pipes of the filter-bed, and from open manholes. A covering of animal charcoal effectually removes any smell from this source. Before the use of lime the surface of the farm became covered with a gelatinous slime, rendering the soil waterproof and effectually preventing filtration. The lime treatment has caused great improvement in this respect ; the resultant sludge is no longer carried all over the farm, but is deposited on the sides of the run-in from the distributing channels, and when necessary is ploughed in with steam tackle. The land is therefore lightened, and the sewage, bereft of its solids and gelatinous matters, easily percolates through the soil. Cropping is quite a secondary consideration, although the farm area is now increased to 713 acres and 515 acres net for filtration. A second effluent-conduit, 2 feet 6 inches in diameter, has been laid, and the whole of the area, having now subdrains $\frac{1}{2}$ chain and $\frac{1}{3}$ chain apart, laid at a depth of 6 feet, is subdivided into three parts, each third having absolute rest for one week in three, the other two being sewaged every alternate 24 hours unless showing visible signs of overdosing. Thus the original idea of broad irrigation has given place to a system of intermittent filtration. The principal crops grown at present are mangolds, osiers, cow-cabbage and cereals. With regard to the growth of sewage-fungus, and the black deposit in drains, it was discovered that sewage-fungus was growing in the river at and below the farm effluent-conduits. On careful examination orange and black fragments were found to come from the conduits. These were found to consist of sulphide of iron, with some oxide of iron, etc., the whole being bound together by a fungoid growth in which microscopical examination revealed *Beggiatoa Alba*, or sewage-fungus, which had been noticed to flourish on the scours and flannel-weed in the river, but not on the silk-weed, which seemed neither to hold it nor to encourage its growth. These fragments were found to exist as slime deposit throughout a large part of the subsoil system. A fine screen was placed at the end of one of the

effluent-pipes, and the flocculent slime was thereby arrested and found to be akin to the larger fragments already referred to. A sample of this deposit in the drains was found on analysis to consist chiefly of ferrous sulphide, organic matter and mineral matter. It was discovered that far more of this deposit existed in the drains of newer and more porous plots than in an old plot which was capable of filtering only one-quarter of the sewage of the newer plot, the drains in the old bed being absolutely free from it. The older beds, filtering more slowly, arrested all the solid matter on the surface, and admitted of more natural changes in purification. The newer and more porous beds were found to filter four times as quickly, and had consequently been overdosed. The sewage being at this time treated to a minimum of 50 grains of caustic lime per gallon, would contain a large excess of carbonate of lime and would carry the more finely divided suspended organic matter, together with fine marl, right through the subsoil into the drains. This filtrant, having passed too rapidly through to be thoroughly purified, admitted of the decomposing bacteria acting upon the organic matter containing sulphides, forming sulphuretted hydrogen, which combined with the iron known to exist in large quantities in the land, and formed a black deposit of sulphides of iron. This difficulty, fortunately, has now been to a large extent overcome. The effective filtering area of the farm has been increased from 362 acres to 515 acres, an increase of 42 per cent. The whole of the sub-drains have been cleaned out, and are now thoroughly aerated. The reduction of the quantity of lime used and careful attention to flooding have tended to the abolition of this difficulty.

The effluent is of a fairly high standard, an average sample containing:—

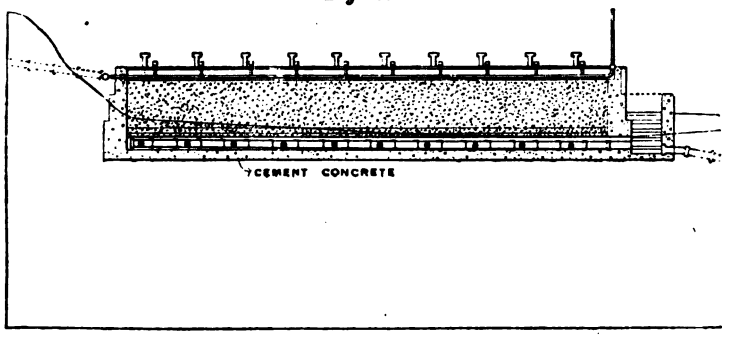
	In parts per 100,000.
Total suspended matter	2·8
Oxygen absorbed at 80° F. in 4 hours	1·3
Albuminoid ammonia	0·13

Although a fairly good effluent is obtainable by the present system of intermittent filtration, the reduction of albuminoid ammonia being considerable, no nitrification takes place. It would seem that the peculiar character of the sewage entirely prevents this. Many experiments have been tried in order to produce an effluent containing nitrates or nitrites, but without success; amongst others was a rough laboratory experiment of the septic tank process, but this failed in its object.

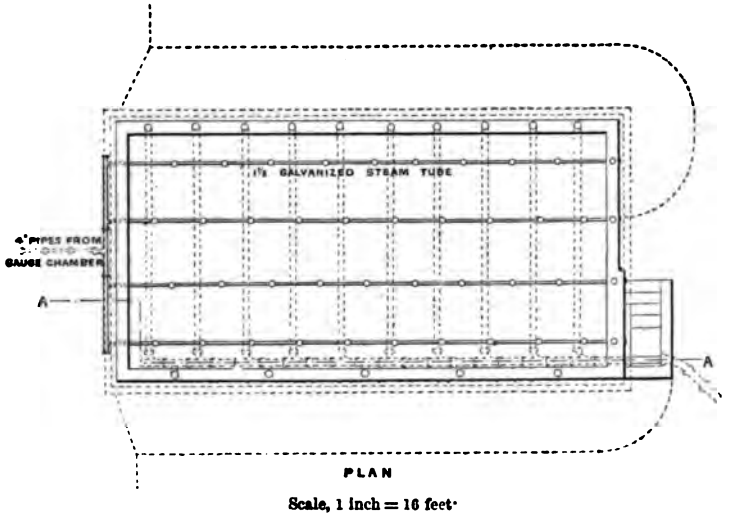
An experimental coal-filter has now been constructed at the *farm* at a cost of £350. It consists of a rectangular tank of cement

concrete, measuring 40 feet by 20 feet, having the sides and bottom rendered internally, *Figs. 3.* Drain tiles are laid in the bottom, 4 feet apart, each being brought up through the wall for aeration. The sole filtering medium is coal, of various sizes and depths, viz., 3 inches of coal over the top of the drain-pipes, retained on

Figs. 3.



LONGITUDINAL SECTION A.A.



PLAN

Scale, 1 inch = 16 feet.

EXPERIMENTAL COAL-FILTER.

a ⅜-inch screen, 6 inches of coal retained on a ¼-inch screen, and 4 feet 6 inches of fine coal retained on a ⅛-inch screen. The sewage is sprinkled over the surface by means of spreaders, of which there are thirty-eight, 4 feet apart, screwed on to ¾-inch galvanized-iron vertical tubes, 1 foot above the surface of the coal; these screws can be used for adjustment to regulate the flow

through the spreaders. The sewage used in this experiment is limed with 40 grains per gallon in the ordinary way, passed through tanks where the solid matter is precipitated, then, passing through a roughing filter of coke, flows in an open channel a distance of 175 yards to a gauging-chamber, which regulates the flow of sewage on to the filter to 200 gallons per square yard per day. This gauging-chamber is 9 feet above the level of the coal, which is the head required to cause the water to leave the spreaders in jets to cover the whole area of the filter. The filter was first used on 19 October, and has been in daily use since. It is worked and rested for 12 hours alternately. Samples of the sewage, before and after filtration, have been analysed every third day and a very satisfactory result is obtained. There is a reduction of free ammonia of 90 per cent., and a reduction of albuminoid ammonia of 80 per cent., the effluent containing 0·055 and 0·05 parts per 100,000 respectively. Up to the present, and it has been working for 20 days, there is absolutely no trace of nitrates. The increase of the amount of chlorine in the effluent for a few days is worth recording. On the second day there was an excess of chlorine in the effluent over that in the sewage of 40 per cent., on the fifth day an excess of 15 per cent., and after 12 days there was an excess of 10 per cent. This excess of chlorine was no doubt derived from the coal, as chlorine is generally present in vegetable juices. It is too early yet to form a definite idea of the action of this filter or its ultimate efficiency. At present the coal seems to be a powerful oxydising agent, and the purification seems to be the effect of oxidation rather than a bacterial process. As a bacterial filter, however, it has not yet had a fair test, and perhaps it has not had time for the necessary bacterial culture.

The works referred to in the foregoing Paper have been carried out by Mr. James Mansergh, President Inst. C.E., Mr. J. E. Swindlehurst, M. Inst. C.E., and Mr. G. T. Lynam, Assoc. M. Inst. C.E., while chemical observations have been made by Professor Dewar and Messrs. Matthews and Lott, to all of whom the Author is indebted for plans and particulars to which he has had access in compiling the Paper.

The Paper is accompanied by drawings from which the Figures in the text have been prepared.

OBITUARY.

GEORGE ARTHUR BIDDELL, second son of Mr. Arthur Biddell, was born at Playford, near Ipswich, on the 28th January, 1824, and was educated at a private school at Grundisburgh, a village near Playford. Having shown considerable aptitude for engineering he was apprenticed in 1840 for seven years to Messrs. Ransomes and May, of the Orwell Works, Ipswich. In 1846, while still an apprentice, he was sent by the firm to superintend the erection of a factory at Tours for the manufacture of compressed wedges and trenails for railways. His apprenticeship expired in 1847, but his services were so highly appreciated by the firm that he was engaged for a period of three years as sub-manager of the works. In 1850 he was appointed assistant to Mr. Hensman, the Chief Engineer of the machinery department at the Great Exhibition of 1851, at the close of which a superintendent's medal and diploma were awarded to him in recognition of his services at the Exhibition. Mr. Biddell invented a great number of labour-saving appliances and agricultural implements, one of his most important inventions being the application of chilling to the manufacture of railway crossings. He also invented a self-regulating gas-burner, which was manufactured at Ipswich. At the close of the Great Exhibition Mr. Biddell accompanied his cousin, Sir George Biddell Airy, the late Astronomer Royal, on a trip into Wales, and on his return he was appointed head of one of the departments of the Orwell Works, subsequently becoming Chief Engineer of the works in 1853, which office he held until March 1876, when he retired from the service of the firm, at that time known as Ransomes, Sims and Head.

Mr. Biddell superintended the construction at the Orwell Works, and the subsequent erection at Greenwich in 1850, of the transit instrument for the Observatory. The transit instrument for the Cape Observatory was also constructed at the Orwell Works under his care in 1853, and in 1859 he made and fixed the great equatorial at Greenwich. Sir George Airy had a high opinion of him, and chose him as a companion in several scientific tours throughout the country.

On his retirement from Messrs. Ransomes, Sims and Head's service Mr. Biddell undertook for a time consulting work, and was in much

request in arbitration cases, but he gradually withdrew from this class of work and devoted himself to the study of astronomy, and to the improvement of his many and various patents. In the early sixties he patented a rifled shot, which was tried at Landguard Fort, and as late as October 1887 he took out a further patent for rifled shot.

In 1883 Mr. Biddell was invited to join the board of the Ipswich Gas Company, and entered with characteristic energy into the details of the working of the concern. In 1895 he was elected Chairman of the Company, and held that post until his death, which took place at his residence, Upland Gate, Bishop's Hill, Ipswich, on the 23rd June, 1901. Mr. Biddell was a most lovable man, of high principles and sterling worth, and is greatly missed in the district in which he lived. He was for forty-six years Warden of Holy Trinity Church, Ipswich.

Mr. Biddell was elected an Associate of the Institution on the 6th March, 1849, and was transferred to the class of Members on the 17th April, 1877.

THOMAS CURTIS CLARKE, born on the 26th September, 1827, at Newton, near Boston, Massachusetts, was educated at Boston Latin School, and at Harvard College, where he graduated in 1848. His preliminary training as an engineer was obtained from Captain John Childe, of Springfield, Mass., under whom he was engaged on various railway surveys. After spending some years on various railways in the United States, and in Canada, he made a special study of bridge building.

As an engineer of great ability in the construction of bridges, Mr. Clarke soon became widely known. One of the first of his works in that direction was the building of the Chicago, Burlington and Quincy bridge at Quincy, Illinois, which spans the Mississippi. This bridge Mr. Clarke built without the intervention of contractors, except for the ironwork. He designed all the machinery and plant, and was so successful that, in spite of a season of unusually high water, he opened the bridge for traffic in fifteen months after the beginning. Mr. Clarke was the senior partner in the firm of Clarke, Reeves & Co., of Phœnixville, Pa., which afterwards became the Phœnix Bridge Company. That Company carried out work all over the United States, comprising not only many of the most important bridges that have been built

in that country, but a considerable part of the elevated railroads of New York.

In 1884 Mr. Clarke became one of the original members of the Union Bridge Company, which in a short time after its formation developed into one of the largest bridge-building concerns in the world. During Mr. Clarke's connection with it, that Company built in Australia the famous Hawkesbury bridge,[1] considered one of the most brilliant achievements of American engineers in foreign lands. Another bridge built about that time—of which Mr. Clarke had special charge—was across the Hudson at Poughkeepsie, the foundations of which are 135 feet below water.

Mr. Clarke died in New York City on the 15th June, 1901, after a short illness, in his seventy-fourth year.

Of Mr. Clarke it was said that he had been concerned in the building of over 80 miles of bridges and viaducts. He was the Consulting Engineer of the Third Avenue and Willis Avenue Bridges at New York, for the design and of construction which he was entirely responsible. Mr. Clarke wrote numerous articles on engineering, many of which are preserved in the Transactions of the American Society of Civil Engineers.[2] Only a few months ago he dealt with the subject of "Engineering" in a work entitled "The Progress of the Century," to which the most eminent men in other branches of knowledge similarly contributed articles. He was a Past-President of the American Society of Civil Engineers, and a member of the American Society of Mechanical Engineers, the American Institute of Mining Engineers, and the American Philosophical Society of Philadelphia, the oldest scientific society in the United States.

Sir Benjamin Baker, Past-President, writes: "The death of my old friend Mr. Clarke will be sincerely lamented by many British engineers, for no one has done more than he to promote the cordial brotherly relationship which now happily exists between American and British engineers. It also severs one more link with the past, for Mr. Clarke's early experience with bridge building was in the days when there was hardly one point of resemblance between American and British wrought-iron bridges, the former being modelled after the type of the original timber-truss construction and the latter on that of the cast-iron shallow-girder system. Mr. Clarke sometimes said that he

[1] Minutes of Proceedings Inst. C.E., vol. ci. p. 2.

[2] Transactions of the American Society of Civil Engineers, vol. i. p. 323, vol. ii. p. 93, vol. iii. p. 255, vol. xi. p. 1, vol. xxv. p. 234.

shuddered when he thought of some of his early bridges, with long, slender cast-iron posts, slight lateral bracing, and totally inadequate pin-connections, even the floor girders being of the latter type, instead of the heavily-riveted low-stressed type which he lived to see substituted in all American bridge-work, as he also saw each country gradually introduce the good points of the other's practice, so that no vital difference now distinguishes European and American bridges."

Mr. Clarke was elected a Member of the Institution on the 5th May, 1874. In 1878 he contributed a valuable Paper entitled "The Design generally of Iron Bridges of very Large Span for Railway Traffic,[1] for which he was awarded a Telford medal and Premium.

CHARLES de NEUVILLE FORMAN, born in Glasgow on the 10th August, 1852, was the eldest son of the late Mr. James R. Forman, whose death took place in July, 1900. The subject of this notice was educated at Glasgow High School, at private schools in St. Andrews, London and Edinburgh, and at Glasgow University. From 1867 to 1872 he served an apprenticeship with the firm of Forman and McCall, and in 1873 he was employed under the late Mr. James Deas, Engineer of the Clyde Trust, who was at the time engaged on the construction of the Queen's Dock. Returning to the office of Messrs. Forman and McCall in 1874, he was admitted as a partner in the following year, the style of the firm becoming Formans and McCall.

Mr. Forman early developed strong commercial instincts and a clear insight into the principles which regulate trade, and with the aid of the opportunities afforded by the associations of the firm, he soon obtained prominence as a leader in railway enterprises. He carried with him a strong power of conviction, was naturally resourceful, and possessed an unusual command of details, coupled with which qualities he had a keen perception of character, with great determination and energy of mind. The firm has been continuously associated with the development of the railway system of the west of Scotland, and through Mr. Forman's energy and ability this undoubtedly received a decided impulse; in various instances long talked of enterprises were formulated, successfully conducted through Parliament, and eventually carried out under his guidance.

[1] Minutes of Proceedings Inst. C.E., vol. liv. p. 179.

His first charge was the Kelvin Valley Railway, opened for traffic in 1878. This was followed in 1880 by the Strathendrick and Aberfoyle Railway, opened in 1884, to which were due the development of Aberfoyle as a summer residence and the formation of a company for the working of the slate on the Montrose Estate, which has since continued a thriving industry. About that time the North Monkland Railway, the Yoker Railway and the Kilsyth and Bonnybridge line were also being carried through.

Mr. Forman's first Parliamentary contest of importance was the promotion of the Clyde, Ardrishaig and Crinan Railway in 1887, which he successfully carried in face of a strong opposition—the powers were, however, subsequently allowed to lapse. The extension of the Strathendrick and Aberfoyle Line northwards by Loch Lomond to form a through line to Fort William had hitherto been kept in view, but this scheme was superseded by the Helensburgh route under the name of the West Highland Railway, extending from Craigendoran, near Helensburgh, to Fort William, a distance of 100 miles. The bill for this undertaking he was instrumental in carrying through Parliament in 1889, and the line was successfully completed and opened for traffic in 1894.

The most important of Mr. Forman's undertakings was the Glasgow Central Railway, which brought the Lanarkshire coalfields of the Caledonian system into direct communication with the Queen's Dock, formed an underground city and suburban line for Glasgow, and opened the way for the extension of the Company's lines into the county of Dumbarton. Powers were applied for and obtained in 1888 after a prolonged struggle, the Caledonian Railway Company having in the interval become possessed of the undertaking. Work was commenced in 1890, and the line opened in 1896. The railway traversed in covered way the busiest thoroughfares of the city, and at such a depth as to necessitate an extensive scheme of intercepting sewers. The execution of the work was much hampered by restrictions for preserving the traffic of the streets from interruption, and what with these and the difficult nature of the subsoil, the many drains, water-, gas-, electric and other pipes to be dealt with, and important structures to be underpinned, the work may well be classed among the most important engineering undertakings of the day.

Consequent on the commencement of the Glasgow Central Railway Mr. Forman was engaged in 1890 in the promotion of the Lanarkshire and Dumbartonshire Railway, and after being defeated in that Session, powers were obtained the following year for the line. This railway forms a natural extension of the

Glasgow Central line and traverses the north bank of the Clyde between Glasgow and Dumbarton, connecting the Caledonian Railway with the riverside lands, and bringing the coalfields and steel works of Lanarkshire on that Company's system into direct communication with the shipbuilding and other industries below Glasgow. Forming as it did a direct invasion of the North British Railway Company's territory, the enterprise demanded unusual skill in its promotion. The extraordinary development of the lands for public works along the route of the line since its opening has fully justified the evidence laid before Parliament. The construction of these lines involved a considerable extent of intricate tunnel and city work.

Besides having carried out various minor lines, Mr. Forman had in hand at the time of his death the construction of extensions of the Lanarkshire and Ayrshire Railways, which afford that Company an independent access between the Lanarkshire coalfields and the port of Ardrossan, the Paisley and Barrhead district railways connecting the last-named line with Paisley and its environs to the south and west. Also the Invergarry and Fort Augustus Railway—this last being the outcome of repeated efforts to obtain the extension of the West Highland line to Inverness.

Mr. Forman's last efforts were directed against the monopoly claimed by the Clyde Trustees, as custodians of the River, to control the power to construct docks thereon, and the prolonged contest extending over three Sessions, and the ultimate passing of the Renfrew Dock and Harbour Extension Bill, to which he devoted the greatest energy, are characteristic of his great determination and ability in this particular sphere.

By his constitutional activity of mind, which permitted no rest, and his devotion to work, Mr. Forman was led to disregard his bodily requirements, and though naturally of a strong and sound constitution, the strain and lack of recreation began to take effect in 1898. With the accumulation of his personal responsibilities at this time, however, he did not allow himself opportunity to sufficiently recruit his strength, and the prolonged Parliamentary contest with the Clyde Trustees, carried on concurrently with his other work, was a severe tax on his health.

In the summer of 1900 he was seized, while in Spain, with an attack of paralysis, notwithstanding which he still pursued his work. This attack being soon followed by other warnings in October of that year, he was forced to suspend work and seek rest abroad. His health, however, continued to fail, resulting in his

death at Davos Platz, Switzerland, on the 8th February, 1901, at the early age of forty-eight.

Mr. Forman had a wide circle of friends, and was well known and highly respected in Scotland, and at the Parliamentary Bar as an engineer unusually powerful in the promotion of commercial enterprises. He was ever ready to give advice to all who might make him their confidant in matters of business or otherwise, and his quick perception and farsight, coupled with self-forgetfulness and a generous disposition, caused him to be burdened with many responsibilities regarding others. Mr. Forman's loss is much felt by many in Glasgow and the West of Scotland, and his short career is a remarkable instance of personal influence in stimulating both industrial and professional activity within his sphere of action.

In much of his work since 1888 Mr. Forman was more or less intimately associated with Sir John Wolfe Barry, K.C.B., Past-President, and at the date of his death was carrying out jointly with Sir John the Ballachulish extension of the Callander and Oban Railway.

Mr. Forman was elected a Member of the Institution on the 6th December, 1887. To the Engineering Conference of 1899 he contributed a Note entitled, "Economy in Handling and Transport of Minerals."[1]

WILLOUGHBY CHARLES FURNIVALL, born in 1837, obtained his early engineering experience on the Great Western Railway of Canada, and in making preliminary surveys for railways in the Western States of America. About the year 1860 he was appointed a District Engineer on the Sind, Punjab and Delhi Railway, and was placed in charge of the construction of part of that line.

In 1867, when Lord Mayo, then Viceroy of India, determined that the Rajputana Railway from Delhi and Agra to the great Salt Lake at Sambhur should be constructed as a State line by the Indian Public Works Department, Mr. Furnivall joined that Department, and was placed in charge of the construction at first of the Delhi Section, and subsequently of the Agra Section in addition. His staff was largely composed of engineers who had little or no previous railway experience. His service to the State was thus of great value in training a body of engineers who were the earliest representatives of the important railway branch of the

[1] Minutes of Proceedings Inst. C.E., vol. cxxxviii. p. 385.

Indian Public Works Department. Some of those who began their railway work under him have held, or are now holding, the highest posts in that branch.

On the completion of the Rajputana Railway Mr. Furnivall was attached to the Government of India as Under Secretary in the railway branch, and afterwards he went as Joint Secretary to the Government of the North West Provinces at a time when the local railways were administered by the local government. Subsequently he had charge of the construction of the Bengal Central Railway, and of the extensions of the Nizam's State Railway, as well as of the working of the open line. Mr. Furnivall left India in 1890 after nearly thirty years of valuable and important work in that country, and returned to England full of health and energy. He soon found work which would have taxed the energies of much younger men, and until quite recently he travelled frequently to Italy and Sardinia, in connection with the supervision of important works and mines.

Mr. Furnivall died at Broadstairs on the 16th May, 1901. His abilities as an engineer, and his qualities as a friend and a chief, endeared him greatly to those who knew him, and specially to those who had served under him. To them his sudden death is a great loss.

He was elected a Member of the Institution on the 2nd December, 1862.

FRANK OWEN, second son of the late Mr. William Owen, of the Foreign Office, and grandson of Sir Richard Owen, was born on the 13th July, 1869. After attending lectures at the Royal School of Mines, South Kensington, he studied practical mining at the East Pool and the Tolgullow United mines in Cornwall in 1885 and 1886. During the following year he was a pupil of Mr. Benedict Kitto, assayer and analytical chemist, and in 1888 he returned to Cornwall and went through a course of mining surveying under Mr. James Henderson, of Truro.

In 1889 Mr. Owen assisted in an examination of the Mount Morgan Gold Mine in Queensland. From 1890 to 1894 he was Assayer and Reduction Officer at the mines of the Frontino and Bolivia Gold Mining Company in the United States of Colombia. He then filled a number of professional engagements, examining and reporting on gold, copper, tin, lead, zinc, and coal mines for London firms and companies, in the performance of which work he visited Norway, Spain, Mexico, the United States, South Africa,

Western Australia, and the Malay Peninsula. In Venezuela he acted for a time as the manager of a gold mine worked by an English company, and finally, in October 1900, he left for the Gold Coast Colony, as one of the engineers for an expedition sent out by the Ashanti Consols Company. Whilst engaged there examining gold-mining propositions for that Company, he died on the 13th July, 1901, from an attack of fever.

Mr. Owen enjoyed the reputation of being a thoroughly capable and reliable mining engineer. He was a Member of the Institution of Mining and Metallurgy, and of the American Institute of Mining Engineers, and a Fellow of the Geological Society.

He was elected an Associate Member of the Institution on the 4th December, 1894.

Khan Bahadur BOMANJI SORABJI died at Bombay on the 14th June, 1901, aged 60. Born in the same city on the 22nd May, 1841, he was educated there at the Elphinstone Institution and in the Engineering Department of the Poona College of Science. In 1861 he was appointed an Overseer in the Public Works Department of the Government of Bombay, in which he subsequently rose to the rank of Assistant Engineer. In 1874 he graduated in Civil Engineering at the University of Bombay, obtaining the James Berkley Gold Medal and several prizes, and at the Delhi Durbar of 1877 the distinction of Khan Bahadur was conferred on him by the Government of India. He retired from the Public Works Department in 1880, and in the following year was appointed acting Professor of Mathematics and Civil Engineering at the Poona College of Science. From 1888 to 1892 he served the Rajpipla State as an Engineer, but was compelled by ill health to resign that post. Mr. Sorabji was well acquainted with German and Portuguese, as well as with many Indian dialects. For a time he acted as Examiner in mathematics, engineering, and science at the Higher Examinations of Bombay University. During the Abyssinian Expedition of 1867–68, in which he took a prominent part, he received a bullet wound in the foot. In 1884 the Bavarian University of Würzburg, to which he had presented a thesis "On Some of the New High Molecular Parafins," conferred on him the degree of Doctor of Philosophy.

Mr. Sorabji was elected an Associate Member of the Institution on the 7th February, 1882.

CHARLES EDWARD STEWART was born on the 6th December, 1849, in Londonderry, Ireland, where his father held the posts of Secretary to the Londonderry Port and Harbour Commissioners, the Londonderry Bridge Commissioners, and the Londonderry and Lough Swilly Railway Company. The subject of this notice, after being educated at Foyle College, Londonderry, the Royal School, Dungannon, and Trinity College, Dublin, served a pupilage to the late Mr. Robert Collins, to whose general practice he succeeded on the latter's appointment as Engineer of the Belfast and Northern Counties Railway in 1875. Mr. Stewart also succeeded Mr. Collins as Engineer to the Londonderry Port and Harbour Commissioners, Engineer to the Londonderry and Lough Swilly Railway Company, and City Engineer.

In his capacity of Engineer to the Londonderry Harbour Board Mr. Stewart had charge of extensive works of the usual description in a port having a long navigable channel. He also built and kept in repair quay walls, tramways, wharves and transit sheds, and several lighthouses; the most important being a screw-pile lighthouse in an exposed part of the Lough, fitted with an occulting dioptric apparatus. As Engineer of the Londonderry and Lough Swilly Railway, he relaid most of the line with new steel rails, and on the gauge of the railway being altered from 5 feet 3 inches to 3 feet, he made such arrangements that he was able to alter the gauge of 12 miles of line between Saturday and Monday, without interrupting any but the Sunday traffic. As Engineer to the working company, he also superintended the construction of the Letterkenny Railway, Co. Donegal, in the years 1881, 1882 and 1883, and subsequently took charge of its maintenance.

As City Engineer, Mr. Stewart designed and carried out several new schemes for the Corporation of Londonderry, the most important being a main sewerage scheme in 1883, an extension of the water-supply, involving the construction of a large impounding reservoir in 1884, 1885 and 1886, and a smaller extension in 1887 and 1888.

Among the more important works Mr. Stewart carried out in his general practice were a water-supply for Buncrana, Co. Donegal in 1884, and in conjunction with Mr. E. McNeilage, the preparation of Parliamentary plans for a light railway, 18 miles long, from Buncrana to Carndonagh in the same year. The contract plans were subsequently prepared; but owing to financial difficulties the construction of the line was not then proceeded with, though it has since been carried out by the Board of Public Works.

In 1890 Mr. Stewart left Londonderry and joined the staff of the London County Council under Sir Alexander Binnie. He was employed in the Water Department, chiefly in connection with the different Water Bills which have been promoted in recent years, and also with the proposed supply for the metropolis from the Welsh mountains. Unfortunately his health broke down, and, after some months' illness, he died at his residence, 4 Park Hall Road, East Finchley, on the 7th July, 1901.

He was elected an Associate Member of the Institution on the 7th April, 1891.

GERALD MERRETT WYNTER, youngest son of the late Dr. Andrew Wynter, was born on the 29th January, 1864. He began his engineering training as a pupil of Mr. S. W. Jenkin, of Liskeard, Cornwall, with whom he subsequently remained as an Assistant on the construction of the Helston Railway, Newquay Waterworks, and Redruth Drainage. From 1886 to 1889 he was engaged in Sweden and Norway, as a District Engineer, on the construction of the railway from Luleå to Gellivara, and from 1890 to 1893 he was similarly occupied on the construction of the Manila Railway. Returning to England, he was engaged for nearly four years in connection with the Newport, Gadshill and St. Lawrence Railway in the Isle of Wight, and in the autumn of 1897 he went to British Guiana to take up work on the extension of the Demerara Railway to New Amsterdam. There he remained until the summer of 1899, when he again came home, and in the following autumn proceeded to Egypt on Sir John Aird's staff for the construction of the Nile Dam. In October, 1900, he joined a special survey party to locate the extension of the Gold Coast Railway—already completed from Secondee to Tarkwa—to Coomassie. On the completion of this work he returned to England, unfortunately suffering from abscess of the liver, from which he died at 30 Upper Berkeley Street, London, on the 14th August, 1901.

Mr. Wynter was elected an Associate Member of the Institution on the 3rd December, 1889.

MATTHIAS ERASMUS WESLEY, who died at his residence, 156 Holland Park Avenue, London, on the 20th August, 1901, aged 80, had for many years taken no active part in professional

work. From an early age he was engaged in connection with the iron trade and with the manufacture of iron for Messrs. R. W. Kennard and Company and Messrs. Kennard Brothers, of London, and for the Falkirk Iron Company. Mr. Wesley, although a shrewd man of business, found time to take considerable interest in music, and was largely instrumental in the establishment of the Royal College of Organists. He was also an active supporter of benevolent societies in connection with the iron trade.

Mr. Wesley was elected an Associate of the Institution on the 1st May, 1866.

CHARLES STROUD WILLIAMS, born on the 8th August, 1849, was the son of the late Mr. James Williams, Architect and Surveyor, of 12 Montague Street, Russell Square, London. After being educated at Merchant Taylors' School and at King's College, London, he became an articled pupil to the firm of Messrs. Easton and Amos, of Southwark and Erith. Subsequently he joined the firm of Messrs. Shaw, Head and Company, of Cannon Street, constructive engineers, and on the dissolution of that firm, entered into partnership with Mr. Thomas Howard Head, and eventually succeeded to the business, carrying it on under the style of Charles Williams and Company, of Millwall and Westminster, in partnership with Mr. Hugh Stanton. This firm was dissolved in 1869, since which date Mr. Williams ceased to have any connection with the engineering profession. He died at Ingoldsby Mansions, Avonmore Road, Kensington, on the 11th April, 1901.

Mr. Williams was elected an Associate of the Institution on the 4th May, 1875.

*** The following death has also been made known since the 23rd July, 1901:—

Member.

THOMAS, JOSEPH; *died* 14 August, 1901.

Information as to the career and characteristics of the above is solicited in aid of the preparation of an Obituary Notice.—SEC. INST. C.E., 30 August, 1901.

Sect. III.

ABSTRACTS OF PAPERS IN SCIENTIFIC TRANSACTIONS AND PERIODICALS.

The Trans-Siberian Railway.

(Engineering, 10, 17 and 31 May, 1901, p. 600 *et seq.*)

The western section of this railway, from Cheliabinsk to the river Obi, is 880 miles long, and was opened for traffic in October, 1896. It runs through a very flat steppe country, with hardly any undulations, intersected by several rivers and covered with long grass, with numerous small lakes with brackish water scattered all over. There is no fresh water. Nearly everything required for the construction, including most of the labour, had to be brought from a distance. With the exception of four girder bridges, all the bridges are of timber. The cost of this section was £4,588 per mile, without rolling stock. The traffic has outrun the capacity of the line so much that in the winter of 1898 there was an accumulation of 7,000 loaded wagons along it. The Cheliabinsk-Ekaterinburg line connects this one with the Ural railway to Perm. It is 150 miles long, cost nearly £4,000 per mile, and was finished in 1896.

The central section, from the Obi to Irkutsk, is 1,137 miles long. The first portion, from Obi to Krasnoyarsk, is 471 miles long, and was finally opened in January, 1898. The estimated cost was £6,357 per mile. The country is at first slightly undulating, and gradually becomes a little hilly. The second portion, from Krasnoyarsk to Irkutsk, is 666 miles long, and was opened for regular traffic in January, 1899. It cost £8,923 per mile. A branch 62 miles long runs to Tomsk, the seat of Government, through very hilly country, and cost £4,393 per mile. The country traversed is at first an undulating plain, and then becomes hilly and almost mountainous where spurs of the Altai, Alatāou, and Sāyan ranges intersect it. The line crosses many rivers and runs through much dense forest, and over a great extent of bogs, whilst the population is very small, so that the difficulties of carrying on the work were greater than on the western section. There are nine girder bridges, besides numerous timber ones on the whole central section. The whole country abounds in minerals. Coal and iron exist in thick beds; silver, lead and copper ores are plentiful on the south side of the main line, towards the mountains, and many mines are worked. Gold is met with in the sand of most of the river beds.

In 1898 the traffic on the central section had already increased to five trains per day each way—one for emigrants, two for construction, and two for general traffic.

Two Tables are given of particulars of the girder bridges.

The Baikal Railway.—The main line from Irkutsk round the south end of the Baïkal Lake will take some time to build yet. Meanwhile, a line has been carried down to the lake shore, 42½ miles long, at a cost of £6,654 per mile without rolling stock. The trains are carried across the lake—42 miles—on an ice-breaking ferry steamer. There are two such. The larger one has 4,200 tons load displacement, and 3,750 I.HP.; it has two screws aft and one forward, and it breaks through ice 34 inches thick, with 8 inches snow-cap, at the rate of 3 miles per hour to 6 miles per hour. The smaller ice-breaker has a load displacement of 1,000 tons. A floating dock has been provided for repairs to these vessels. The length of the line round the south end of the lake is 199 miles—from Irkutsk to Myssovaïa—and involves many tunnels and other heavy work along the rocky shores of the lake.

The Trans-Baïkal Railway starts from Myssovaïa, and is 687 miles long. The first part is very mountainous, involving heavy work and steep gradients. The line as originally projected has not been carried beyond Stretensk, which is now the terminus. From here the steam navigation starts down the Chilka and the Amur. At Chilka the main line diverges to join the Eastern Chinese Railway, and is now practically finished. The Trans-Baïkal Railway was commenced April, 1895, and opened for regular traffic July, 1900, and cost £11,158 per mile, without rolling stock. The population of the district is extremely small, and the climate very severe. The principal article of transport is tea from Kiakhta, amounting to 27,438 tons per annum. There are seven fair-sized girder bridges on this line, and a great many timber ones.

On the Trans-Baïkal portion an additional hindrance to the work was the Siberian cattle plague, which carried off nearly all the horses. This yielded ultimately to scientific treatment. Except timber, of which there was plenty of excellent quality, all materials had to be brought from Vladivostock to Khabarovka, and thence up the Amur. On the whole, the work was heavy—in cutting through hard and rocky ground, in retaining works as protection against river erosion, and in culverts and bridges. Owing to the floods in the short summer, much of the work had to be done in winter, entailing novel and ingenious arrangements to contend with the intense cold of these regions. Caissons for foundations were made of timber. The mineral riches of this region are phenomenal. On the Chinese Frontier Branch—215 miles long—there are fifty-three metal bridges, and double the number of timber ones. The construction was commenced in *1899*, and is to be completed in 1902. The estimated cost is *£12,492* per mile, without rolling stock. The rails are 72 lbs. per

yard, but otherwise the construction is the same as that of the rest of the line—single track. The Amur Railway is 950 miles long, and supersedes the line originally planned from Stretensk to Khabarovka. This, together with the branch to Port Arthur and the connection with the North China Railway at Shan Haïkwan, is being built by a private company under arrangement with the Russian Government. Work was commenced in 1897 and it is to be completed in 1902. The Ussuri Railway—478½ miles long—is the sixth and last section of the Trans-Siberian Railway proper, and runs from Khabarovka to Vladivostock. It was commenced in 1891 and finished in January 1895. The cost of construction was £8,113 per mile for the first half and £9,594 per mile for the second half, without rolling stock. The climate being very unfavourable only native workmen could be employed. There are four principal metal bridges with spans from 280 feet to 322 feet, besides 322 smaller ones, mostly of timber.

The Perm-Kotlas Railway is treated here as a continuation of the Siberian system, although it runs altogether in European Russia, namely, from Perm on the Kama to Kotlas, where the Northern Dvina begins, formed by the confluence of two other rivers. Thus the Siberian produce is brought so far by rail and then goes down the Dvina to Archangel for shipment. It is 537½ miles long, was commenced in January 1895, opened for regular traffic in 1899, and cost £7,553 per mile, without rolling stock. The first part of the line, from Perm, goes through a fairly populous country; then it passes through virgin forests and swamps, entailing corduroy road and a great deal of timber framing, or low bridgework, to carry the road. There are four good sized metal bridges, with spans from 210 feet to 350 feet, besides twenty-two smaller ones and over 500 timber bridges.

C. H. M.

Underpinning on the Extension of the Orleans Railway to the Quai D'Orsay.[1] H. DE LA BROSSE.

(Revue Générale des Chemins de fer, February, 1901, p. 149.)

The Paper is a description of the means taken to underpin the buildings on the Quai D'Orsay above the new station recently built by the Orleans Company. The area covered by the buildings underpinned was 25,830 square feet, and the property consisted of two distinct buildings, one, an old house six storeys in height, badly constructed, divided into numerous flats; and the other, offices in connection with the Government's Bank of Deposits, a more recent building, five storeys in height and well built. The difficulty of the work was increased, inasmuch as the buildings

[1] *Minutes of Proceedings* Inst. C.E., vol. cxxxv. p. 400, and vol. cxxxviii. p. 513.

were immediately above the entrance to the station, occasioning great irregularity in the spans of the girders and the arrangement of the intermediate columns between the two masonry abutments.

Wherever possible twin girders were erected, at 4 feet 6 inches centres, on each side of the partition walls, connected together by cross girders with jack arches in cement concrete springing from their lower flanges. The abutments and foundations of the columns were put in first, followed by the piercing of the partition walls for the girders, when the girders were placed in position, and before receiving the walls they were loaded by means of sand, lead ingots, and by pressure from hydraulic jacks, to the extent of their permanent load; the girders then having taken their deflection, were wedged in this position whilst the permanent load was transferred to them. By this means no trace of settlement appeared in the walls of the buildings above. The total weight of steel employed was 1,600 tons. The whole of the work was carried out without any interference whatever with the occupiers of the rooms in the buildings concerned.

Several plans and sections are given in the text.

J. A. T.

The Strengthening of Bridges upon the St. Gothard Railway.

E. Lubini.

(Schweizerische Bauzeitung, 1901, p. 23.)

The Author points out that the strengthening of iron bridges may be rendered necessary by error in the original calculations, by faulty material or workmanship, or by damage. Latterly, however, even comparatively new bridges have needed strengthening, either owing to the increased loads and speeds of trains, or because modern practice will not permit of such high stresses in the material as were formerly thought satisfactory. The Author discusses various methods of strengthening, and describes the means adopted in the case of the Trodo Bridge on the Bellinzona-Luino part of the St. Gothard line. It is comparatively easy to strengthen the girders which support the roadway and also the wind braces, but to deal satisfactorily with the rest of the structure is more difficult.

The Trodo Bridge has parallel lattice girders with double braces. The railway is carried on the bottom boom. The clear span is 114·8 feet, total length 116·4 feet, breadth 16·07 feet, and height of girders 11·08 feet. The track is laid upon a curve of 1,968 feet *radius*. From tests and calculations it was found that the stresses were as follows when stated in tons per square inch of cross section :—

	Actual Stress.	Permissible Stress.	Overloading.
			Per Cent.
Top boom	6·41	4·76	35
Bottom boom	7·05	4·76	48
Tie rods	5·71	4·76	20
Struts	4·13	3·49	18

This bridge was strengthened in the manner shown by illustrations in the original, using a parabolic bow-string girder applied above the top boom, using the boom itself as the tie beam.

The alterations were designed by Mr. Bouzanigo, then bridge engineer on the St. Gothard Railway, and the work was carried out by the Author.

Diagrams and loading are given, and the method of calculation is explained in the original. The traffic was not interfered with during the strengthening works. The case of another bridge is also described where the strengthening members were applied below the bottom boom.

E. R. D.

A Proposed Ventilating System for the Park Avenue Tunnel, New York City. ALBERT A. CARY.

(Engineering News, 8 August, 1901, p. 93.)

The Park Avenue Tunnel is about 2 miles long and is divided into one central tunnel with two tracks of rails in it, and two side tunnels with one track each, the division walls having arched openings in them. At present the only ventilation consists of openings in the top of the centre tunnel. Between 500 and 600 trains pass through daily, the average time for the passage of a train being 3½ minutes. Mr. Cary proposes to close all existing openings and to place a fan every 250 feet to draw the foul air from the top of each of the tunnels by special ducts, fresh air inlet passages being also provided at each fan. The section of the tunnel is 841 square feet; each fan is 12 feet diameter and 6 feet broad, running at 120 revolutions per minute, and discharges into its own chimney 100 feet high. There would be forty such fans and chimneys. Each would require 40 HP. to work it. They are to be driven electrically.

C. H. M.

The Jungfrau Railway New Electric Locomotive.

(Schweizerische Bauzeitung, 1901, p. 43. Figs.)

The design of the new electric locomotive for the Jungfrau Railway differs very considerably from that of the engines first employed, and is fitted with two six-pole tri-phase motors, each weighing 4,620 lbs., which are supplied with current at 450 volts to 550 volts, and at 750 revolutions per minute and 38 periods each develops 120 HP. After 3 hours' work at full load the temperature only rises 77° F. above the surrounding air. The current employed when running light is 25 amperes at 500 volts, and the energy lost 4,200 watts; the maximum current on short circuit is 800 amperes at 500 volts. The characteristic curves and also other curves are given in a diagram in the original. The winding of the inducing part is arranged in 108 notches, each with three leads, and the Author gives details of the sizes and arrangement of the wires. The energy developed is transmitted from each motor through a worm to a pinion which gears with another upon the driving axle. The ratio is 12·66:1, so that at the normal speed of the motors the engine travels at 4·8 miles per hour. To one of the motors is coupled direct a small six-pole direct-current dynamo developing 25 volts and 150 amperes. The current produced is sent through the field windings of the main motors when descending the incline, and thus the motors become ordinary tri-phase generators.

The locomotive was built by the Schweizerische Lokomotiv- und Maschinenfabrik in Winterthur, and it has been tested with the following results.

The total weight of the locomotive is 13·4 tons. For the trials one wagon of 4·1 tons weight and a passenger car weighing 3·9 tons with a load of 6·2 tons were used, so that the whole train weighed 27·6 tons.

ASCENDING.

Journey Number.	Rise.	Speed.	Potential.	Current in 1 Motor.
	Per Cent.	Miles per Hour.	Volts.	Amperes.
1	9·5	5·02	500	60
2	21·5	4·84	500	109
3	24·1	4·84	500	123
4	25·0	4·8	490	133
5	24·1	4·8	565	110

E. R. D.

Calculations for Spiral Buffers. VICTOR MEYER.

(Zeitschrift des Vereines deutscher Ingenieure, 1900, p. 1791.)

The main point in these buffers is that they should allow of full compression without loss of elasticity and without fracture. Failures in these respects are too frequent on German railways. There seem to be no reliable formulæ for determining the correct dimensions, etc.

The following Paper is an attempt to supply the deficiency.

There is a very simple formula for calculating worm and round spirals.

Let f = breaking point with a load P kilograms,
r = the average radius,
n = the number of spaces,
$b\,h$ = dimensions of flat steel,

the $$f = \frac{0{\cdot}00366\ \mathrm{P}\, r^3\, n\, c}{b^3\, h}.$$

C = a coefficient representing the quality of the steel. The above expression is given by Saint Venant,[1] and agrees with the results of Bauschinger's experiments.

In the case of cylindrical worm spirals the force P acts at the end of the arm r, and $2r\pi n$ is the length of the steel under torsion. St. Venant's expression must be multiplied by $r^2 2\pi n$. The $f = \theta r^2 2\pi n$, where θ in millimetres represents the torsion at 1 millimetre radius at 1 millimetre from the fixed point. Considering the case of five spirals each taken separately the expression becomes—

$$f = \frac{0{\cdot}00366\ \mathrm{P}\,(r_1^3 + r_2^3 + r_3^3 + r_4^3 + r_5^3)\ \mathrm{C}}{b^3\, h}.$$

This may be simplified by considering the relation of the distance a from centre to centre between one spiral and that next it to the length of the radius of the complete spring r or r_1.

The value of f_2 is found in terms of f_1 from the equation—

$$f_2 = f_1 \frac{r_2^3}{r_1^3},\ \text{so}\ f_3 = f_1 \frac{r_3^3}{r_1^3} \ldots f_n = f_1 \frac{r_n^3}{r_1^3}.$$

Thus $$f = f_1 + f_2 + f_3 \ldots f_n.$$

Now substituting $\frac{a}{r}$, which varies between 0·066 and 0·225—

$$f_2 = f_1\left(1 - \frac{a}{r}\right)^3 \cdot f_3 = f_1\left(1 - 2\frac{a}{r}\right)^3 \ldots f_n = f_1\left(1 - [n-1]\frac{a}{r}\right)^3.$$

The Author gives a Table and examples worked out by its aid. From this Table it appears that with a greater number of windings

[1] Zeitschrift, 1889, p. 137.

a limit is reached when no increase of strength is obtained, and this line stands in a fixed relation to the reciprocal value of $\frac{a}{r}$. In conclusion the Author states that the determination of the value of C awaits further experiments. In spite of the valuable researches of Back and Bauschinger, there are still wanting, especially as regards flat steel, similar experiments with Bessemer, Thomas, Siemens, and puddle steel.

W. A. B.

Bessemer Steel in Railway Bridges. P. Joosting.

(De Ingenieur, 1901, p. 33.)

In Holland, before the year 1880, Bessemer steel was very generally used for the cross girders and rail-bearers of railway bridges; the main girders, however, being mostly constructed of wrought iron. In the specification for the two materials the bending tests were alike; the tensile strengths required were 36 kilograms per square millimetre for the wrought iron and 60 kilograms to 65 kilograms for the steel (23 tons per square inch and 38 tons to 41 tons per square inch).

There had been difficulty in getting steel to come up to the standard desired, the metal supplied having been very irregular in quality. Some small test girders that were built of steel broke at stresses calculated to be about half the strength of a plain bar.

Although the results of the tests were unfavourable, there was no serious doubt of the safety of the bridges for several years after construction, and although cracks were observed in some parts these were simply cut out and replaced by whole metal.

Serious alarm was occasioned, however, when it was discovered that in the bridge over the Koningshaven, at Feijenoord, one of the rail-bearers was nearly broken in two, both the bottom flange angles and the web plate being completely separated. The bridge is about 700 feet long in three spans, two fixed and one draw span. On investigation, over eighty cracks and fractures were discovered, the most of these being in the top flanges of the rail-bearers.

The strain in some of the remaining floor girders was measured under ordinary traffic. The highest stresses were found in the rail-bearers next the swing span—16 kilograms per square millimetre (10·16 tons per square inch). The average in the other rail-bearers was about half this amount.

The metal of the broken girders was tested for strength and also subjected to chemical analysis. Judged by the results of these tests the metal was not entirely inferior, but was wanting in uniformity; and the limit of elasticity was very high, sometimes *rising to* four-fifths of the ultimate strength.

The whole of the floor girders in the two fixed spans were taken

out and replaced by others of mild steel (Siemens-Martin) having a strength not greater than 28 tons per square inch.

The way in which the work was actually carried out is detailed at length in the Paper.

J. G.

Actual Stresses in Bridges. H. VAN OORDT.

(Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1900–1901, p. 61.)

This Paper is the record of a very complete test of a railway bridge over the Maas at Heusden, consisting of two large through spans each 110 metres (361 feet) long, and seven small platform spans each 43·4 metres (142 feet) long.

The main girders of the large spans had curved top flanges and double N bracing, the small span girders were parallel flanged with single N bracing. The cross girders, with the exception of the end ones, were supported at the centre of the main girder flanges so as to admit of rotation. The rail-bearers had sliding supports on the intermediate cross girders, and were divided into two and three separate sections over the small and large spans respectively. The loading consisted of trains of one or two engines followed by wagons. The measurements taken included changes of angular position, deflections, changes of total length of main girders and rail-bearers, and changes of length over short portions of flanges from which the stresses were calculated. As regards deflections there was close agreement between the amounts observed and the values derived from calculation. This was not the case with the angular deviations, and for the main girders of the small spans the differences were considerable and could not be accounted for. The measurements of the extensions of the main girders and the rail-bearers showed that notwithstanding the movable bearing of the rail-bearers on the cross girders, the rail-bearers were still subjected to longitudinal stresses. The measurements of strain by the elasticimeters were taken mostly on the web members towards the ends and centres of the main girders. For example, one group of strain measurements was taken over the first and second diagonals and first and second verticals of one of the large span girders; the total number of instruments in use simultaneously was thirty-two, four at each end of each strut or tie, each set of four being placed at the corners of the rectangle occupied by the inside and outside plates and angles.

The object which had been aimed at by the method of supporting the cross girders on the centre of the main girder flanges was shown by the observations not to have been attained, as there were considerable differences between the stresses in the inner and outer plates of the main diagonals and the inner and outer flanges of the vertical struts. For the first and second verticals of one of the large span girders, the stresses on the inner faces were 0·3 kilo-

gram and 1·7 kilogram per square millimetre, against 1·0 kilogram and 2·85 kilograms per square millimetre on the outer face (0·2 ton per square inch against 0·63 ton, and 1·08 ton against 1·81 ton per square inch).

This twisting of the main girders was attributed to the stiffening action of the transverse wind-bracing frames.

By the use of four elasticimeters at one cross section the true longitudinal stress in the piece was derived by simply taking the mean of the four readings. The comparison of this mean stress with the actual value at each point gives the true effect of secondary stresses. In four web members at the north end of one of the large span girders the observed stresses exceeded the true longitudinal stress by amounts varying from 9 per cent. to 71 per cent. Curiously enough, however, the calculated longitudinal stresses are higher than the true values, and about equal to the maximum observed in each of the four members.

One set of observations on the end cross girder of one of the large spans led to the conclusion that it was subjected to a direct longitudinal stress and that besides it suffered horizontal bending.

It was seen also that, in spite of the central supporting of the cross girders, the distribution of the load of a train between two main girders was not according to the law of the lever, being apparently modified by the stiff cross wind-bracing frames.

The Paper is supplemented by tabular statements occupying a dozen pages, giving in detail the whole of the observations made.

Besides the Author a very considerable *personnel* was engaged on the work connected with the tests and calculations.

J. G.

Stresses in Cross Girders. A. C. C. G. van Hemert.

(Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1899–1900, p. 1.)

In a previous communication[1] the Author had given a theoretical investigation into the value of the stresses in cross girders, along with the results of observations. In the theoretical part he had considered the deformation of the rectangular framework formed by the cross-girders, vertical struts and overhead cross-bracing, but had neglected the effects due to the unequal stresses in the inner and outer plates of the main diagonals, the torsion of the main bottom flange and the resistance of the lower wind-bracing. This he proposed to remedy in the present Paper.

Before entering on his main subject the Author discusses the mathematical theory of the strength of a rectangular framework, basing his treatment on the theory of minimum work, for which purpose he takes as the two unknown stresses the direct stress and the bending moment at the centre of the overhead cross-piece.

[1] *Tijdschrift* van het Koninklijk Instituut van Ingenieurs, 1897–98, p. 108.

Coming to the main purpose of the Paper, the inequality of the stresses in the outer and inner plates of the main diagonals is calculated to modify the stress in the cross-girder flanges by amounts which, according to the tabulated figures, are roughly about 5 per cent. of the primary stress. The modification of the stress values arising from the resistance offered by the lower flange to being twisted is shown to be practically negligible, not more than ½ per cent. The effect of the resistance to distortion on the part of the lower wind bracing, may, according to the Author's figures, amount to as much as 10 per cent.

The Author applies his results to two bridges. He tabulates the effects due to the above-mentioned causes and compares the final result with the stress as derived from actual measurement. There are 15 cross-girders in the Bommel Bridge, and in 7 of these the difference between the calculated and observed stresses is under 5 per cent. The greatest difference is 17 per cent.

The Author shortly discusses the live load effects on the stresses in the cross-girders and comes to the conclusion that the above-mentioned differences may fairly be set down as the dynamic effect of the live load, and as more directly arising from the shocks due to the irregularity of the running surface. In arriving at this conclusion, considerable use is made of Melan's results.[1]

J. G.

Strength of Rail-Bearers. N. C. Kist.

(Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1899–1900, p. 100.)

On the occasion of a periodical scraping and painting of the Koningshaven Bridge at Rotterdam fractures were observed in the flange angles of several of the rail-bearers. The number of fractures was fifty-eight in all, twelve of which were total fractures of angle bars, and forty-six partial ruptures of the cross section. These rail-bearers were of Bessemer steel.

No similar fractures, *i.e.*, perpendicular to the length of the rail-bearer, could be discovered in other bridges, but cracks running along the flange-angles were found in two bridges, the material of one of these being steel, of the other wrought iron.

Simultaneously with the search for fractures in rail-bearers, the stresses occasioned by the ordinary traffic were investigated by means of recording elasticimeters, the type used being that of Manet.

The outcome of this part of the work did not tend to a clear view of the real state of stress in the rail-bearers; the variation of stress in what appeared to be almost precisely the same circumstances being very considerable. For example, in one of the rail-bearers of a bridge at Kuilenburg the maximum stress was 0·4

[1] *Minutes of Proceedings* Inst. C.E., vol. cxvii. p. 411.

kilogram per square millimetre (0·25 ton per square inch), while in another of the same construction and dimensions, and under the passage of a similar train, the stress was 10·1 kilograms per square millimetre (6·4 tons per square inch).

The actual stresses also differed considerably from the results of calculations in which due regard was had to the conditions of the ends of the rail-bearers, simply supported or fixed. In one case the calculated stress was 3·5 kilograms per square millimetre (2·2 tons per square inch), and the observed maximum was 10·1 kilograms per square millimetre (6·4 tons per square inch).

The stresses in the top flanges were more irregular than those in the bottom. In the bridge at Kuilenburg the stresses on the outer and inner edges of the top flange were 6·1 kilograms and 10·1 kilograms per square millimetre (3·87 tons and 6·4 tons per square inch) respectively, while in a bridge at Bommel the stresses on the two top flange edges were practically alike and equal to 4·1 tons per square inch. In the first of these bridges the rail-bearers were further apart than the gauge of the line while in the second they were under the rails.

An important point brought out by the stress measurements was that the presence of a joint in the rail did not affect the maximum stress in the rail-bearer so long as the joint was not directly supported, but that when, as in the Maas Bridge at Rotterdam, the joints rested directly on a cross sleeper, the passage of every wheel induced a momentary increase in the stress.

The Paper is accompanied by a plate showing details of construction of the bridges referred to, together with prints of the records taken with the elasticimeters.

There was a considerable discussion after the reading of the Paper, from which it appears that there was no general agreement as to the origin of the fractures in the rail-bearers, several hypotheses being put forward.

J. G.

Continuous Beams. Prof. Ramisch.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, 1901, p. 183.)

This Paper treats the problem of continuous beams, more particularly those with ends inclosed, in a manner which is comparatively simple (no calculus is introduced) and yet powerful in producing results.

The Author takes as the fundamental case the cantilever loaded with isolated loads, and obtains expressions for the angle through which any section of the beam turns and for the deflection at any point, including those parts of the cantilever outside of the loaded portion. It is more particularly this inclusion of the unloaded portions of the cantilever which enables the results obtained in

the consideration of this elementary case to be extended to the more complicated problems.

Taking a cantilever loaded with p per foot run for a distance q from the fixed end, and also with concentrated loads X and Q distant x and q from the fixed end. Also let there be a bending moment M acting at the outer end. Then the deflection under Q is obtainable directly from the equation—

$$\mathrm{E\,J}\,y = \tfrac{1}{2}\,\mathrm{X}\,x^2\left(q - \frac{x}{3}\right) + \frac{1}{3\,\mathrm{Q}\,q^3} + \mathrm{M}\frac{q^2}{2} + \frac{1}{8\,p\,q^4}.$$

A similar expression holds for the deflection under X.

The tangent at Q moves through an angle determined by the equation—

$$\mathrm{E\,J}\,\theta = \mathrm{X}\frac{x^2}{2} + \mathrm{Q}\frac{q^2}{2} + \mathrm{M}\,q + \frac{p\,q^3}{6}.$$

By introducing conditions as regards the deflection at the different points and conditions of fixity of the end of the beam, the various continuous beam problems can be solved. For example, suppose a beam q feet long continuous over two equal spans, built in at both ends and loaded with a uniform load p per foot run. The bending moment at the abutments and centre pier is the same and equal to $\dfrac{1}{48\,p\,q^2}$; the reaction at the central pier $\dfrac{1}{2\,p\,q}$.

W. B.

New Instruments for Bridge Testing. J. Schroeder van der Kolk.

(De Ingenieur, 1900, p. 278.)

The Manet extensometers[1] were used by Government engineers in Holland from the year 1877 up to a few years ago, when they were replaced by others designed by Mr. Kist.

By these new instruments either the maximum strain suffered by a bar during a certain time, or the varying values of the strain during the whole time of observation, can be determined.

To a point of the bar, the strain in which is to be investigated, is fastened one end of a steel band lying along the bar and having its other end formed into a hook which engages on to the pin of a small crank.

The shaft of this crank rotates in bearings fixed to a second point of the bridge, and it is evident that any change of the length between the two fixed points will cause a rotation of the diminutive shaft; and to measure the change of length, a long pointer, having a scale at its outer end, is fixed to the shaft. A small projection from the pointer leaves its trace on a surface of lamp-black and so

[1] Minutes of Proceedings Inst. C.E., vol. cxx. p. 381.

indicates the maximum strain. The steel band is kept taut by a special spring fixed to the pointer and some other part of the instrument.

The actual change of length is enlarged forty times at the end of the pointer.

To obtain a record of the variation of the strain, instead of its maximum value only, a pointer is used having a Berlin silver point, which scratches its record on a strip of metallic paper wound round a drum fixed in position by screws. The rotation of the drum is effected by clockwork fixed to any convenient point of the bridge and communicating its motion to the drum by cords and small pulleys. The same clockwork can be arranged to drive two or more drums.

The article is illustrated by a large number of figures.

J. G.

Permanent Way of the Strasburg Tramways.

(Mittheilungen des Vereins deutscher Strassenbahn und Kleinbahnverwaltungen, 1901, p. 169.)

The system belonging to the Strasburg Tramway Company includes considerable lengths both of town and country lines.

The permanent way of the town lines is of an exceptionally heavy character. The rail on which the wheel runs is of the Vignoles section, and, instead of a lip on the inward side of the space for the wheel flange, there is another rail of somewhat lighter section bolted through cast-iron distance-pieces to the main rail. The two rails thus united are supported on longitudinal metal sleepers.

The total weight per metre of single line is 167 kilograms, or nearly 340 lbs. per yard.

On the outer town lines the longitudinal metal sleeper is not used, and on the light railway section the check rail is, of course, dispensed with.

On the sharp curves an attempt has been made to avoid the usual grinding of the wheels against the rails by causing the wheel on the outside of the curve to ride on its flange. For this purpose rectangular bars of hard steel are placed between the main and check rail, and resting on the distance pieces at such a level as to make the tread of the wheel clear the top of the Vignoles rail.

With wheels of 750 millimetres (2·46 feet) diameter, and 15 millimetres (0·6 inch) flanges, a pair of wheels, gauge 1 metre, will, when made to run in the manner indicated above, take naturally a curve of 25½ metres (83·6 feet).

The sharpest curves on the Strasburg lines are of 18 metres (59 feet), and these are traversed with ease by the vehicles in ordinary use, which have wheel bases of 1·8 metre and 2·4 metres

(6 feet and 7·8 feet). On occasions, however, wagons with rigid wheel bases of 5 metres (16·4 feet) pass over these curves, and this would hardly be possible with the ordinary system.

J. G.

Use of Tramway Lines for Postal Traffic.

(Mittheilungen des Vereins deutscher Strassenbahn und Kleinbahnverwaltungen, 1901, p. 167.)

Since 1 March, 1901, the postal traffic between the general office and a certain district office in Frankfort-on-the-Maine, has been conducted by means of specially built cars run on the city tramway lines, and obtaining energy for traction from the overhead electric conductor.

The most prominent advantages of this are the removal of a certain amount of horse traffic from the streets, and a reduction in the number of journeys between the two offices from 50,000 to 20,000 per annum.

The body of each car weighs 3 tons. The motor is a 4-pole continuous current machine of 15 HP., and can run the car at 12½ miles per hour.

Drawings of the car are given with the Paper.

J. G.

The Construction of the Klausenstrasse in Switzerland.[1]

F. Becker.

(Schweizerische Bauzeitung, 1901, pp. 109, 121. 6 Figs.)

The Author points out that the construction of roads in the Swiss Alps is essential for the prosperity of the country. Looking back over the history of these roads he notes that in 1800 the French built the first modern road and this was over the Simplon Pass, the distance from point to point in an air-line was 18·6 miles, and the height of the top of the pass 6,593 feet above sea-level. Then followed the construction of the roads over the Bernhardin, 1818; Julier, 1820; Splügen, 1823; Maloja, 1827; and during the same period also a number of other important roads were constructed.

The Author then points out the great military and commercial importance of the new road over the Klausen, made between 1891 and 1899; but the two cantons of Uri and Glarus took up the work principally for commercial reasons.

The original projects were drawn up by Diethelm for the Uri portion and by Schindler for the Glarus part; these projects were,

[1] Minutes of Proceedings Inst. C.E., vol. cxliii. p. 345.

however, considerably altered in execution, which began in Uri in 1893 and in Glarus in 1895, the work being in the charge of J. Müller for Uri and N. Hefti for Glarus. The gradients were all kept below 9 per 100. On the Glarus side the Schindler project was not entirely followed, as two tunnels of 233 feet and 416 feet, near Früttbach, were adopted, instead of high retaining walls and half galleries and about 82 feet of tunnel.

The total cost has been £69,124 for the Uri portion and £22,560 for the Glarus part, or about 38*s.* 3*d.* and 39*s.* 9*d.* per yard respectively.

The State subscribed 80 per cent. of the cost, and also the sum of £6,000 to the canton of Uri. The length of the road in the Uri canton is 22·8 miles and in the Glarus canton 6·07 miles, making 28·87 miles in all.

The width of the road is 31·48 feet, and the actual gradient does not exceed 8·5 per 100, except in one place, 328 feet long, where it is 10 in 100.

The Author gives a Table and a number of details of the names of the contractors for the various sections of the work, and the cost price per yard, with dates of completion. E. R. D.

The Air-Compressing Works at Billancourt. GEORGES CAYE.

(La Nature, 20 April, 1901, p. 331.)

The Paris Omnibus Company has recently substituted mechanical traction by means of compressed-air motors for the animal traction, on a certain number of its tram-lines, representing a total length of 57·78 miles. In order to provide the power, it became necessary to erect important works at Billancourt on the banks of the Seine, capable of furnishing 16 tons of air hourly, at a pressure of 1,137 lbs. per square inch. There are seven sets of aerogens, each of which consists of a compressor and an engine, indicating from 650 HP. to 1,000 HP. per unit. The triple expansion horizontal engines are designed by Mr. Mekarski, who has been entrusted with the entire installation. Two of the cylinders are coupled in tandem and the third is coupled in a similar way with the low-pressure air-cylinder. The engine cylinders are respectively 20·72 inches, 27·91 inches and 51·18 inches in diameter; the stroke is 55·12 inches and the main shaft may make from 50 revolutions to 70 revolutions per minute. The air is compressed in three stages, and careful arrangements are made for cooling and drying. The boilers of the multitubular type, supplied by Babcock and Wilcox, have a heating surface of 2,260 square feet. The feed-water is clarified and heated to 150° C. to soften it. There is likewise a complete electric light installation. Illustrations are given of the engines and air-compressors. G. R. R.

A Mountain in Motion. L. Reverchon.

(La Nature, 30 March, 1901, p. 276.)

Attention is directed to the grave anxiety caused to the inhabitants of the valley of the Areuse (canton of Neuchâtel) by the signs of movement of the adjacent mountain, which have become evident since the winter frosts and snow. No less than eleven openings or crevices, one of them 13·77 inches wide and causing a sinkage of the roadway of nearly 10 inches, close to the village of Noiraigue, have made their appearance, and the government engineer estimates that a mass of rockwork, amounting to not less than 650,000 cubic yards, is liable to slide down into the valley, to block up the Jura-Simplon Railway, to dam up the river and to cause serious damage to the village and factories by the air-pressure due to the dislocation and fall of these enormous masses of rock. Pending the execution of the works which have been proposed to arrest the movement of the mountain, the engineers have devised a series of check-registers, made of cement-fillets, which are arranged across the cracks and lines of sighting-rods constituting a complete triangulation of the area affected, have been established. Further, a theodolite station has been erected to take careful observations of movements in the detached part of the mountain, and a very complete photographic record has been obtained of the more dangerous spots. Several of these photographs are here reproduced in facsimile.

G. R. R.

Improvements in Skeleton Weirs.

(Schweizerische Bauzeitung, 1901, p. 50. 4 Figs.)

The Author points out that the system of skeleton weirs, although to all appearance very simple, has not received very wide application, as it is not suitable for great differences of water-level, nor can a passage for traffic be easily arranged.

The usual difference of water-level for which this type of weir is used does not exceed 10 feet to 12 feet, and the separate sluices must not be too large, or they cannot be manipulated by an attendant upon the small footbridge. Mr. Guillemain has brought out an improvement which facilitates the manipulation of the sluices, and it consists of an iron lever bent in the form of a hook having its fulcrum upon a fixed cross shaft behind the sluices. This arrangement has been satisfactorily used upon six weirs upon the River Fulda between Cassel and Münden during the past 2 years.

E. R. D.

Pumping-Station on the Rhine-Marne Canal. I. Hermanuz.

(Zeitschrift des Vereines deutscher Ingenieure, 1901, p. 145.)

This canal joins the Rhine and the Rhine-Rhone Canal at Strasburg; the summit, 416·67 feet above mean sea-level, is surmounted by fifty locks. Four years ago the surface width was 49 feet with a 32·8-feet bottom and depth of 5·9 feet; since then the depth has been increased and the locks lengthened to admit 300-ton barges. Additional pumping-power being necessary, the Esslingen Machine Factory was entrusted with the erection of two 80-HP. turbines to drive two dynamos, and furnish, through a 2·30-inch conductor, a current of 900 volts to 1,000 volts to three motors, working a high, intermediate and low-pressure centrifugal pump. A water-supply of 88 gallons to 330 gallons per second with a fall of 35 feet to 36·73 feet is available for the turbine which runs at a moderate speed. The entries are on the Muhlberg system, an automatic regulator cuts out the turbine when from any cause the dynamo is suddenly relieved.

The switch-board is provided with volt- and ampere-meters for all three machines, besides resistance-regulators, safety-plugs and shunts. An illustration of the centrifugal pumps with vertical shafts is given. Their performance exceeded that specified in the contract. The form of paddle varied slightly from that prescribed by Hermann. The motion of the paddle causes a slight swirl in the inflowing water; on this account the angle of entry was so designed that friction was avoided. The upper edges of the pumps are 3½ inches below the surface, and scarcely disturb the surface. Ring-valves close each pump. The Author describes the method adopted in ascertaining the volume of water supplied and delivered, and a Table is given showing the results obtained with the pumps, brake and electrical power. At full pressure 80 per cent. of the power generated was effective, at three-quarter pressure 75 per cent., and at one-half pressure 72 per cent. It was also ascertained that turbines, dynamos and motors give the best results when worked at a low speed.

The actual results were even better than those shown in the Table, as it was found a leakage of 10 gallons to 24 gallons per second took place.

The general results of the experiments were so satisfactory that the authorities put a stop to them before many interesting theoretical points could be verified, but not before an effectual system of working had been determined, the scheme of which is given. At the comparatively trifling cost of £34,313 a very efficient pumping-station of great value commercially has been provided, and one that will bear close scrutiny in every way.

W. A. B.

A 10,000-Ton Balanced Sectional Floating Dry Dock.

WM. T. DONELLY, M.E.

(Engineering News, 2 May, 1901, p. 314.)

This is the largest floating dry dock that has ever been constructed of timber. The constructors are Messrs. Faber du Faur and Donelly of New York. A historical sketch of the development of floating docks is given. This one consists of five sections, each 110 feet 10 inches wide and 80 feet long, with 20-inch spaces between them and 30 feet overhang at each end, making the length over all 466 feet 6 inches. The depth at the centre is 13 feet 6 inches, and the height of the sides or wings 36 feet 9 inches. The maximum draught which can be lifted is 26 feet; the maximum lifting power is 10,000 tons and the available width between the wings is 92 feet. The whole is built of yellow pine, and a special study has been made of the stresses to which the transverse trusses between the floor and the bottom are subject. This is fully explained, and particulars of construction and scantlings are given. The floor is planked longitudinally and the bottom transversely. The body of each section is divided longitudinally into six parts (besides the ends forming part of the wings) by five watertight bulkheads, to prevent the water running to one side in rolling. There are also two transverse bulkheads in each section, to prevent the water running to one end when connecting the sections. These are connected together by strong oak timbers on the deck of the wings (known as locking logs), 40 feet long and 24 inches by 28 inches section. The machinery is designed for simplicity and reliability, economy being a secondary consideration. The engines are simple, vertical, direct acting, and the boilers are vertical with vertical tubes. One set is placed on the top of each of the wings of the middle section; and power is transmitted to the other sections by sliding couplings and universal joints. The pumps are single-acting lift pumps with square timber barrels, with india-rubber foot and bucket valves working on grids. There are two pumps in each wing of each transverse section of the dock. Experience has proved this class of pumps to be very efficient and long-lived for such docks.

The Paper is illustrated by numerous drawings.

C. H. M.

Report of the Alsatian Steam-Engine and Boiler Association.

(Bulletin de la Société Industrielle de Mulhouse, April, 1901, p. 132.)

The annual report for the year 1900 is here given by the Chief Engineer, Mr. Walther Meunier. The number of boilers on their books is about 2,800, and there was no explosion during the year.

Some 637 steam-engines were indicated, and 35 tested by a brake, etc.

A Table is given in this report of about 100 different boilers, on which evaporative tests were made. The coal used is given, French, German, or Belgian, as also the percentage of ash, etc., varying from 6 per cent. to 25 per cent. The pressures of steam are added, also the evaporation per square metre of heating surface, and kilograms of water per kilogram of coal. Some few boilers are provided with steam superheating pipes. The heating surface is mentioned in each case. Twenty-five steam-engine tests were made to determine the consumption of steam. A detailed test of a mechanical stoker as against hand-stoking by the stoker of the association resulted in $1\frac{1}{2}$ per cent. economy in favour of the latter. Sixty-one analyses of water were made, and 20 calorimetric tests on different coals used in the district, German, French, Belgian. Details are mentioned of an accident to a superheater on a Babcock boiler.

B. D.

Special Report upon Turbines and Regulators at the Paris Exhibition. F. Prášil.

(Schweizerische Bauzeitung, 1901, pp. 53 *et seq.* 27 Figs.)

The Author is one of the Professors at the Zurich Polytechnic, and the Paper gives a long report upon the most important improvements in turbines and their regulators, which were exhibited at Paris in 1900. He points out that the exhibits at the exhibitions of Philadelphia, 1876, and Chicago, 1893, drew the attention of European manufacturers to the advantages of the vanes used in the Hercules and the Victor turbines, both American types—the European type differs principally in the form of the regulator. Diagrams of the buckets are given, and the designs of a number of firms are discussed and illustrated—among them Teisset, Joly, Laurent, and Vigreux, the latter firm uses special roller bearings. In the Impulse type the angle of the vanes was 25° in the casing and 22° degrees in the moving part; in the axial Girard, 25° and 15° or 16° respectively; and in the partial Girard, 20° and 12° respectively. The Author then describes the special types of turbines built by Singrun Brothers of Epinal; the special arrangement of the apparatus at the electricity works of Zamora is illustrated and develops about 5,500 HP. The description of the Francis type of turbine, as made by Ganz and Company of Budapest, follows. This has a horizontal shaft, develops 1,000 HP., with a fall of 225·7 feet to 244·4 feet at 300 revolutions, and is to be used at Jajce, in Bosnia. It is controlled by a double-acting hydraulic Servomotor, which is illustrated and described in detail.

The Rüsch-Sendtner regulator is then described, and a repro-

duction of a diagram taken from an automatic recording apparatus is given to show the close regulation of speed, even although the load was purposely varied rapidly up and down. The Author then describes and illustrates a number of other types of regulators dealing with all the chief modern forms of the apparatus.

E. R. D.

Oil-Engine Trials at the Royal Agricultural Society's Show at Cardiff.

(Engineering, 28 June, 1901, p. 828.)

Only six firms competed. The points to which the attention of the judges was directed in awarding the prizes were (1) simplicity, workmanship and durability, combined with facilities for repairs; (2) economy in getting to work and attendance; (3) consumption of air and circulating water; (4) governing power and uniformity of speed; (5) efficiency; (6) cost; (7) weight compared with power; (8) facility of transport and stability; (9) arrangements and capacity for carrying oil and circulating water. The awards were made with reference to the whole of these points. The first two days the engines ran on full load with a light oil—Royal Daylight Oil of 0·79 specific gravity.

In the starting trials there was very little difference in the times required from lighting the lamps to starting—they all took about 15 minutes; from 0 minute to 4 minutes after that full speed was attained, and from 1 minute to 5 minutes after starting, full load. After putting on full load Crossley's engine gave six puffs of smoke only, after which there was no more smoke. With the other engines the smoke disappeared in from 1½ to 9 minutes after putting on full load. On the last day the oil was changed to Russoline, specific gravity = 0·82. The consumption of Russoline oil on the full-power trials varied from 0·68 lb. to 0·71 lb. per B.HP. per hour, Messrs. Crossley's engine consuming the lowest quantity.

The first prize was awarded to Messrs. Crossley Brothers, and the second to Messrs. Ruston and Proctor. The engines of these two firms developed from 14½ B.HP. to 17 B.HP. on the different trials.

C. H. M.

The Sirocco Fan.

(The Engineer, 21 June, 1901, p. 650.)

The peculiarity of this fan consists in the blades, which number as many as 64 in a 30-inch fan; measured radially the blades are one-sixteenth the diameter of the fan; axially however, the blades

are long, measuring 18 inches in that direction for the size referred to. The outer edges of the plates are bent forwards in the direction of rotation. The inlet to the inside of the fan and the outlet from the circumference are approximately equal to the area of the fan itself. It is claimed that the special form of blade employed reduces the loss of power due to the formation of eddies, and that the velocity of the air on leaving the fan exceeds the peripheral speed of the blades by about 80 per cent. In one type of bearing, designed to avoid difficulty when dealing with heated gases, the journal is connected with one side of the fan and the bearing is supported by tension-rods from a cylindrical bracket attached to the casing. Tests made with these fans have shown an efficiency of over 90 per cent.

A. W. B.

Experiments with a 300-HP. Laval Steam-Turbine.

WILH. JACOBSON.

(Zeitschrift des Vereines deutscher Ingenieure, 1901, p. 150.)

Apart from its many other advantages, the Laval steam-turbines occupy comparatively little space, and their high speed fits them specially for electromotors. A 100-HP. steam-turbine gave such satisfactory results in the paper and cellulose factory at Pötschmühle in Bohemia that a second of 300 HP. was erected to drive a rotatory generator of 350 cos ϕ kilowatts and 330 volts, with fixed winding and rotating magnet as illustrated. It has four high and eight low-pressure jets. The low-pressure jets are 0·35 inch in diameter, the high-pressure 0·78 inch. The latter are only used at starting or to maintain the pressure when it falls rapidly.

The turbine makes 10,500 revolutions, the gearing shaft 750 revolutions per minute. The power is transmitted by hemp bands. The air-pump condenser, with a 14-inch piston and 16½-inch stroke, is in an underground cellar and driven by a separate 12 HP. motor. Steam is supplied from a Dürr water-tube boiler of 3,035 square feet heating surface through a Kausch superheater of 732 square feet heating surface at a pressure of 12 atmospheres. The effective power and expenditure of steam were exactly determined. Working at 300 HP. the turbine used 18 lbs. of dry saturated steam (*bei trocknem gesättigem Dampf*) per HP. per hour, 17·2 lbs. at a temperature of 446° F., and 14·97 lbs. at 527° F., the initial tension at the jets being 9 atmospheres. The arrangements and the results of the main experiment, which lasted 5 hours and 8 minutes, and was carried out 14 days after erection, are fully stated, while the Table below shows how the specific expenditure of steam increases as the load is reduced.

Number of Low-Pressure Jets.	Steam Pressure at the Valve.	Temperature of Steam.	Initial Pressure at Mouth of Jets.	Low Pressure.	Revolutions per Minute.	Brake Power.	Specific Expenditure of Steam.
	Atmospheres.	° Celsius.	Atmospheres.	Millimetres.		HP.	Kilogram per HP. per Hour.
8	10·28	192·34	8·61	685·3	754·66	342·1	7·012
7	10·0	190·0	8·6	685·6	750·0	297·8	7·05
6	9·75	190·0	8·5	691·9	760·0	252·6	7·12
5	10·0	190·0	8·6	698·4	753·0	[214·3]	[7·0]
4	10·5	188·0	8·5	701·5	750·0	165·0	7·27
3	11·0	187·0	8·5	709·0	762·0	120·5	7·47
2	11·0	187·0	8·5	715·4	762·0	74·5	8·95
1	11·2	188·0	8·5	717·5	762·0	30·8	9·74

W. A. B.

Statistics of Turbine Construction in Switzerland.

(Schweizerische Bauzeitung, 1901, p. 128. 1 Fig.)

This article gives a Table and a graphic diagram showing the rapid growth of the turbine industry in Switzerland since the year 1844. The data have been supplied by the five principal firms occupied in the business. In 1844 Escher, Wyss & Co., of Zurich, had already built turbines; and in 1854 J. J. Rieter began similar work in Winterthur; in 1860 Theodor Bell, of Kriens; and in 1863 M. B. Roy, of Vevey, followed. The latter firm is now known under the title of "Ateliers de Constructions mécaniques de Vevey;" and in 1886 the firm of Faesch and Piccard was founded in Geneva, and is now known as Piccard, Pictet & Co. The Table shows the great increase in the size of the units in recent years owing to the demand for electric-power plants. The following figures are extracted from the Table. In the 6 years ending 1849, 53 turbines, with 1,330 HP., averaging 25 HP., were built; in the 10 years ending 1859, 221, with 8,739 HP., averaging 39·5 HP.; in the next similar period, 493, with 26,825 HP., averaging 54·4 HP.; in the period ending 1879, the figures were 1,006, with 66,688 HP., averaging 66·3 HP.; in the period ending 1889, they were 1,840, with 133,579 HP., averaging 72·6 HP.; and in the period ending 1899, they were 2,231, with 400,474 HP., averaging 179·5 HP. The total up to the end of 1899 was 5,844 turbines, giving 637,635 HP.

E. R. D.

Ball-Bearings for Heavy Machinery. HEIBECK.

(Zeitschrift des Vereins deutscher Ingenieure, 1901, p. 73.)

Hertz and Auerbach's researches, the Author states, are inadequate to solve the important questions involved in the experiments he was called on to undertake on behalf of the German Arms and Munition Factory of Berlin, together with Mr. Riebe, its engineer.

A special device was employed whereby three balls, one on the top of the other, were subjected to vertical pressure, the central ball was also in another series of experiments replaced by a flat circular plate whose periphery was the same as that of the two other balls. The observations were by a reflecting apparatus which magnified 500 times. Pressure was applied by a 5-ton press of special construction supplied Dr. Amsler. The diameter of the balls ranged from $\frac{3}{8}$ inch to $\frac{2}{8}$ inch. The results are given in two sets of Tables (I. for balls, and II. for balls and plane surfaces).

The Author next treats of the theoretical determination of the amount of friction, then describes the special apparatus employed by him in ascertaining the same practically. The result of experiments with various kinds of bearings showed that the best form for heavy work was two rings, the inner surface having a groove the depth of which was two-thirds the radius of the balls.

With pressures of 2,204 lbs. to 6,614 lbs., and 65 revolutions to 780 revolutions per minute, the coefficient of friction varied very little indeed, and averaged 0·0015. Up to a pressure of 10,800 lbs. with 780 revolutions per minute, the balls and bearings were faultless. For the past year all the ball bearings manufactured by the Berlin Arms and Munition Factory have been constructed on the basis of these experiments, which were concluded in March 1899; since then bearings of greater size have been made and worked under a pressure far exceeding the above, and this is due to the care and attention paid to the perfection of the material and workmanship of all parts of the ball bearings.

W. A. B.

The Loading of Balls and Ball-Bearings. Dr. SCHWINNING.

(Zeitschrift des Vereines deutscher Ingenieure, 1901, p. 332.)

Although ball-bearings are largely made use of in cases where the load carried by the bearing is small, as for example in bicycles, yet they are employed to only a very small extent for *heavy* loadings, since under these conditions the results obtained have fallen far below expectations. This is due to the fact that

the method generally made use of for determining the breaking stress of the balls—namely, the compressing of the balls between hardened plates—gives numbers which are far too high, the condition of the plates having a much greater influence on the results than that of the balls. To obtain values of the breaking stress independent of external conditions, the ball to be examined must be compressed between two equal balls. The Paper contains a picture of the apparatus employed for this purpose and reproductions of photographs of the fractured surfaces of two broken balls. If the ball is frequently loaded and unloaded, it is found to break much more readily than under a continuously increasing load. In the latter case the ball breaks into two hemispherical pieces whilst under the varying loading two small shear wedges pressed into the material at the top and bottom of the ball make their appearance. The nature of the surface of fracture is of importance, as it shows whether the ball has been hardened all through or whether the hardening only extends to a small depth, leaving the interior soft.

The actual value of the breaking stress is of merely secondary importance, since a ball in a bearing breaks by the cracking off of small pieces, and it is hence of more value to determine the loading under which the first crack appears on the ball. To make the cracking more readily visible, several spots on the ball are etched with dilute hydrochloric acid, and after each loading the surface is examined under the microscope. In this way it is found that cracking often begins with less than one-tenth of the breaking load.

Another important measurement in the testing of balls is that of the maximum value of the mean pressure in the surfaces of contact. The theory of this question has been given by Hertz in his work, "Ueber die Berührung elastischer Körper," according to which the mean pressure is the same for all curvatures. The results of Auerbach, however, who carried out a long series of experiments on brittle materials such as glass and rock crystal, show that this pressure increases very rapidly with the curvature. This deviation from Hertz's theory is described by Auerbach and others to the action of surface stresses, but the Author considers it more probably due to small differences in the hardness, large balls being much more difficult to harden than small ones. The Author has made experiments with pairs of cylindrical rods of copper and brass of various diameters; the axes of the two rods were arranged at right angles to one another, the curved surfaces, which were in contact, being covered with a thin layer of lamp-black in order to show the extent of the pressure surface. The results obtained in this way show that the curvature has no appreciable influence on the maximum value of the mean pressure over the surface of contact.

The bearing should be as hard and tough as the balls used in it, and should be tested by running at about 750 revolutions per *minute in conjunction* with good balls, the load being gradually

increased to its highest possible value. Any soft places on the surface of the bearing which comes into contact with the balls are by this means readily discovered.

The permissible load for balls of diameter D may in all cases be taken as $P = k D^2$, and for cylinders of diameter D and length L as $P = k_1 D L$, the coefficients k and k_1 being determined experimentally.

T. H. P.

Manufacture of Tubes. DIEGEL.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, 1900, p. 361.)

This is a long Paper of about 80 pages with five large plates, describing the manufacture of tubes of iron and copper, and alloys of the latter metal, and recording the results of investigation into the influence of the different methods of manufacture on the strength of the material. The Author first deals with tubes having a longitudinal seam; these may either be lap-welded, spiral-welded, or butt-jointed and welded. In this class also are included corrugated furnace tubes and those of copper and brass with a lapped longitudinal hard-brazed joint. The most important of the various ways of turning out weldless tubes is the Mannesmann process, and the Author enters into this in great detail, discussing several theories of the precise mode in which the tubular form is obtained. A few pages are devoted to cold-drawn tubes. The subject of the material for tubes is next taken up. On the ships of the German Imperial Navy all pipes for conveying water or steam, with the exception of the main steam pipes, are of copper, with copper or bronze flanges. Until lately, condenser tubes were made of tinned brass. It was found, however, that as soon as the tin began to wear off, the galvanic action between the brass of the tubes and the copper or bronze of the other parts of the condenser, rapidly destroyed the brass, and now the tubes are of copper, alloyed with 1½ per cent. of tin. Tubes of water-tube boilers in the German Navy are of mild steel galvanised externally. This, however, is not a durable protective coating, and various other kinds have been tried, among others a compound tube by Thornycroft, bronze inside and steel outside. The effects of the various corrosive agencies in and about boilers and ships and the protection against these is discussed. The inspection and testing of tubes and the relation between the strength of the original material and that of the tubes forms the completion of the article.

W. B.

High-Pressure Steam-Pipes.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, 1901, p. 198.)

For the last few years the Society of German Engineers have been considering the fixing of standard dimensions for steam piping, and having now completed their deliberations, have issued recommendations and rules as to materials, thickness of pipes, and standard joints.

These standards have reference to pipes of from 30 millimetres to 400 millimetres (1·18 inch to 15·7 inches) diameter, and for a working pressure of eight to twenty atmospheres (113·6 lbs. to 284·4 lbs. per square inch). For pipes of over 300 millimetres (11·8 inches) diameter a set of dimensions for fifteen atmospheres (213·3 lbs. per square inch) pressure has also been worked out.

Cast iron is permissible for all sizes of pipes when the pressure is not greater than eight atmospheres, for pipes up to 150 millimetres (6 inches) when the pressure is between eight and thirteen atmospheres, and not at all above this pressure.

When wrought iron or steel is used the pipes walls are not to be subjected to a greater stress than 400 kilograms per square centimetre (2·54 tons per square inch).

In the case of welded tubes the metal must be thick enough to get a proper weld, but not so thick as to deprive the pipe of a certain degree of flexibility. These requirements are sought to be fulfilled by the following formula for pipes up to 200 millimetres (8 inches) diameter:—

$$s = \frac{p\,D}{700} + 1,$$

where s is the thickness in millimetres, p the pressure in atmospheres, and D the diameter of the pipe in millimetres.

For diameters from 200 millimetres to 400 millimetres the thickness of metal is to increase until at the 400 it corresponds to the formula—

$$s = \frac{p\,D}{800}.$$

For copper tubes up to 100 millimetres diameter—

$$s = \frac{p\,D}{400} + 1{\cdot}5,$$

and for above 125 millimetres diameter—

$$s = \frac{p\,D}{400}$$

There are also regulations as to flanges and metallic packings. Tables of standard dimensions and drawings of standard pipe joints are given in an Appendix.

W. B.

Gauge-Glasses. O. Schott and M. Herschkowitsch.

(Zeitschrift des Vereines deutscher Ingenieure, 1901, p. 339.)

The Authors have examined boiler gauge-glasses made of various kinds of glass with respect to (1) their power of resisting cold and hot pressure, (2) their sensitiveness towards change of temperature, and (3) the extent to which they are attacked by the water of the boiler. The glasses included one of French origin, much used for the purpose, one English (Scotch tubes) and four of Jena manufacture, including a new boro-silicate glass prepared especially for making gauge-glasses and known by the name of "Durax" glass. The experimental results led to the following conclusions:—(1) All the glasses, whatever their composition, resist cold hydraulic pressure in a very high degree, the pressure for tubes of external diameter 19 millimetres ($\frac{3}{4}$ inch), and the ordinary thickness varying from 170 atmospheres to 330 atmospheres. (2) In the case of a hot boiler pressure without external cooling, all the glasses resist from 35 atmospheres to 40 atmospheres. (3) The behaviour of the different kinds of glass, when artificially cooled by spraying with cold water, depends mainly on the coefficient of thermal resistance and varies widely. The Durax glass resists a pressure three to four times as great as that which fractures the English and French glasses. (4) So long as the feed-water does not contain large proportions of free alkali its destructive action and that of the steam on the glass at high pressure, is far smaller for the Durax glass than for any of the other makes.

T. H. P.

The Friction of Lubricating-Oils at High Temperatures.

Sigmund Kapff.

(Zeitschrift des Vereines deutscher Ingenieure, 1901, p. 343.)

In a Paper published on this subject by Thurston in 1899, it is stated that the coefficient of friction of lubricating oils decreases as the temperature rises to a limit of about 82° C., from which it is concluded that heating of the bearing to this degree must not be regarded as harmful and that a hot bearing need not be cooled unless its temperature exceeds 100° C. The Author draws attention to the fallacy of these views which only take account of the frictional resistance, and which, even if this latter were the principal factor to be considered, would not hold true generally. Leaving aside the question of the danger of a hot bearing, the small saving of energy due to the low value of the coefficient of friction of the oil would be far more than counterbalanced by the amount of heat wasted in keeping all bearings at a temperature of 82°.

Two causes contribute to the heating of a bearing. (1) A quantity of energy, varying widely with the consistency of the oil, is expended in overcoming the internal friction (cohesion) of the oil and is partly converted into heat. The amount of heat produced in this way is relatively small, for, experimenting with a 100-HP. engine and a good lubricating oil, the Author finds the temperature of the bearing at the end of the working day to be 35° C., whilst with more viscous oils it reaches 38° and 40°, and with a cylinder oil 46°. (2) An oil possessing small adhesion may, either by pressure or high speed, be removed from contact with the rubbing surfaces, which may then be raised even to a red heat. There can hence be no doubt that something is wrong with a bearing which becomes heated to a temperature of 80°; either the oil used is bad, or too little of it is employed, or possibly the bearing is dirty or otherwise out of order.

The Author goes on to consider the conditions to be fulfilled by a good lubricating oil, which are as follows: (1) It must be free both from acid and solid particles and must not resinify or become acid, while its flash point must be suitable to the purpose for which it is intended; (2) it must have a suitable adhesion; and (3) at the temperature at which it is used its frictional resistance must be as small as possible. The ordinary method of judging of the value of an oil from its price, appearance, specific gravity and viscosity is entirely fallacious, since none of these factors have any bearing on the good or bad lubricating properties of an oil. A rapid method of examining lubricating oils is described by the Author.

T. H. P.

Means for the Prevention of Rust, and their Industrial Importance. Dr. Theodor Koller.

(Glaser's Annalen für Gewerbe und Bauwesen, 15 April, 1901, p. 161.)

Although there are many means to hand for guarding against rust and for protecting iron from its effects, it cannot be said that the existing methods are entirely satisfactory. It is pointed out that in the vast majority of cases in which rusting takes place the substance formed is either the hydrous oxide or the oxyhydrates of iron, and the rust is thus the highest product of oxidation which this metal is capable of forming in atmospheric air. Under certain conditions, in the vicinity of factories which emit sulphurous fumes, cases have occurred in which iron has been attacked in other ways herein described. The chemistry of rust-formation is discussed, and the agency of water containing certain salts in solution is explained. The behaviour of iron surfaces under a coating of oil paint is examined, and the appearance of rust in minute specks on polished iron surfaces, in its bearing upon the mode of attack on the metal, is investigated. The Author refers to

the importance of an impervious coating of oil varnish over the entire surface, and traces the origin of the decay of paint on metal to minute cracks, often due to expansion and contraction. Various protective processes are discussed in detail, and the importance of a surface-covering of a chemically-combined oxide of iron, as preventing any further attack, is insisted upon.

G. R. R.

The Use of Coke-Oven Gas in Gas-Engines. E. REUMAUX.

(Bulletin de la Société de l'Industrie Minerale, 3rd series, vol. xv., 1901, p. 493.)

This, a communication made to the late Congress of Mining and Metallurgy at Paris, describes an application, at a group of by-product ovens at Lens of the gas remaining after heating the ovens to the production of power. The proportion so available depends mainly upon the character of the coal, being insignificant when the proportion of volatile matter is 20 per cent., but becoming of importance when it reaches 23 per cent. In Westphalia it is estimated that the surplus may reach 25 per cent. of the whole amount of gas given off, but this the Author considers to be excessive. At Lens the maximum has been found to be 12 per cent. for the following conditions:—

Coal charged (with 23 per cent. volatile)	7 tons.
Moisture	10 per cent.
Ash	9 „
Three burners and seven air intakes per oven—	
Temperature of air	320° C.
„ „ gas	50° C.
Time of coking	36 hours.
Thickness of flue-wall of oven	130 millimetres.

Yield of gas per ton of coal, 325 cubic metres; density 0·482.

The surplus gas originally used for raising steam, tar distilling, laboratory heating-stoves, &c., has, during two years, been partially applied to a Letombe double-acting gas-engine driving a dynamo. Considerable difficulty was experienced at first, owing to the valves becoming clogged with deposited tar, but this has been overcome by a rapid method of purification, including a coke-scrubber and ferric oxide purifier, which remove tar and sulphur. This, however, will shortly be superseded by improved methods of condensing the by-products, which include recovery of cyanides and sulphur from the crude oven gas. The specific gravity of the gas so purified is 0·614, with a calorific power of 4,200 calories per cubic metre at 15° C.

The amount of gas disposable under favourable conditions from 120 ovens, burning 7-ton charges in 36 hours, is 1,000 cubic *metres* per hour, which, at 830 litres per HP.-hour, as determined *by experiment*, corresponds to 1,200 HP., or 10 HP. per oven. If

the waste flame is used for raising steam, the water evaporated being about 0·75 kilogram per kilogram of coal charged, the yield per oven at 15 kilograms of steam per I.HP.-hour amounts to 9½ HP. The data of two trials of the engine are given in tabular form, the average power realized being 21·99 I.HP. and 24·53 I.HP. for consumption per I.HP. of 0·827 cubic metre and 0·773 cubic metre of gas respectively. The yield of the dynamo was from 0·697 to 0·746 of that of the engine, and the thermal utilization in the engine 0·174 to 0·186 respectively.

H. B.

Further Progress in the Direct Use of Blast-Furnace Gas for Power. F. W. Lurmann.

(Stahl und Eisen, vol. xxi., 1901, pp. 433, 489.)

This is a report in continuation of previous communications on the same subject, the difficulties arising from variations in composition of the gases and their low calorific value, the presence of dust, metallic and other vapours, and water vapour being specially considered. No inconvenience has been found to result from variation in composition and as regards heating power; owing to the gas being free from hydrogen the amount of air required for combustion is so much less than is necessary with illuminating gas, that for equal power the capacity of the cylinder with blast furnace gas need be only about one-half more than that of an engine using town gas. The question of purification from dust and water vapour is a more important matter, and many important installations for cooling and cleaning the gases have been established in Germany, Luxemburg, and Austria, which are described in considerable detail. These are mostly combinations of ordinary dust-catchers with wet scrubbers and sawdust purifiers, the cost of such arrangements varying with the quantity treated per hour and the more or less complete separation of the dust from £1,500 to £7,000 for capacities of 350,000 to 1,000,000 cubic feet per hour. The cost for four furnaces making 300 tons each per day, corresponding to about 140,000 cubic feet of gas per minute, when sawdust purifiers are used, is estimated at £67,500. The plan adopted at Differdingen in Luxemburg is in marked contrast to these very expensive methods. Here the purification is effected by a centrifugal exhausting fan in which the gas is subjected to the action of a current of water which removes nearly all the suspended matter that has escaped the ordinary dust-catchers of the blast furnace. The gas arriving at the fan with 2·8 grams per cubic metre is delivered with only 0·238 gram, or about 0·1 gram per cubic foot. A centrifugal drum washer has been tried for the same purpose, but does not seem to be capable of running continuously for any very long time. At the beginning of April 1901, blast furnace gas-engines of a total of 77,595 HP.

were partly at work, but mostly under construction in the different European countries. Of these 36,050 HP. are of the Seraing pattern, 13,350 HP. of the Deutz Otto Company, 16,300 HP. by Oechelhauser, 5,105 HP. by Körting Brothers, and 6,740 HP. by the Nürnberg engine works. The largest engines made are those of Seraing up to 650 HP. in a single cylinder; the Deutz Otto Company making their largest unit of 300 HP., which in twin-tandem or double-tandem combination, may be brought up to 1,200 HP., 2,000 HP. or upwards in a single engine. The arrangements adopted by the different makers, as well as that of the blowing engines, which is one of the principal applications, are very fully illustrated.

The Paper closes with the description of two new forms of blast furnace charging arrangements which prevent the loss of gas during the charging period. From present observations it appears that 3·5 cubic metres (12½ cubic feet) of gas are required to produce one effective HP. per hour, and that for 12·5 HP. to 28 HP. per ton of iron made will be available for other purposes after satisfying the works requirement. The saving of 6*s.* per ton estimated by the Author in former communications seems to be in a fair way of realization.

H. B.

A Mine-Surveying Problem. V. Kadainka.

(Berg- und Hüttenmännisches Jahrbuch der k. k. Bergakademien, 1901, p. 105.)

The royalty of the Miröschau-Libuschin Colliery Company in the Kladno coalfield runs in an east and west direction. In the eastern portion there are two shafts (Johann shafts) 60 yards apart, and the underground workings from these shafts are directed towards the southern boundary, and have recently assumed a westerly extension. The Kladno coal deposit consists of basins of various sizes often separated by anticlinals, sometimes of considerable width, containing no coal. The western workings referred to encountered an anticlinal of this kind and a cross-cut was driven to find the coal. At the same time it was decided to put down a borehole in order to obtain further information as to the position of the coal seam in the west, the point at the surface selected for this borehole being intended to be the site of a new shaft subsequently to be sunk. The distance of the borehole from Johann shaft No. 1 was not to be less than 2,300 yards. In 1896 the borehole struck a seam of coal 30 feet in thickness at a depth of 1,620 feet. Tubes were left in the borehole so that when the shaft was being sunk the water could be taken to the Johann *shafts* and there raised to the surface. Consequently the cross-cut he western portion of the field had to be driven to the borehole

by the shortest path. The manner in which this interesting problem was solved is described in great detail by the Author. A survey of great precision was required as the cross-cut had to strike accurately a borehole only 5·9 inches in diameter. The survey included the following operations: (*a*) selection of a suitable system of triangulation so that the Johann shafts were included in it; determination of the meridian at one of these points, as well as of the astronomical azimuth of one of the lines of the triangulation passing through one of these points; (*b*) measurement of a base-line; (*c*) triangulation and equalisation by the method of least squares; (*d*) establishment of connection with the mouth of the borehole and the triangulation; (*e*) establishment of connection with the centre-points of the two shafts and the triangulation; (*f*) shaft-plumbing and connection of surface and underground surveys; (*g*) traversing underground; (*h*) determination of the direction, and (*i*) verification survey. The holing, or in other words, the finding of the borehole, was effected on December 28th, 1900; the lateral deviation of the cross-cut axis from the borehole axis being 3·9 inches.

B. H. B.

Electrical Power in Mines and Ironworks. KÖTTGEN.

(Verhandlungen des Vereins zur Beförderung des Gewerb-fleisses Sitzungs-Bericht, 1901, p. 80.)

The Author points out that mines, being frequently situated in mountainous districts where water-power is plentiful, present a case in which electrical transmission can be very profitably employed. The waste gases from blast furnaces and small cheap coal can also be made available for the production of energy where electrical power transmission is adopted.

In connection with the subject of the Paper, the question most open to discussion is whether the current employed is to be continuous or alternating, monophase current being excluded. Three-phase current is the only class of alternating current mentioned by the Author.

As regards transmission, the Author considers that for distances over 2 kilometres (1¼ mile) phase current is preferable, the voltage being over 10,000.

In the majority of cases it is preferable to convert this phase current, for actual use in the motors, into continuous low tension current, 500 volts to 600 volts. Polyphase current may be used directly, however, in mines to drive drainage pumps, ventilating fans, hauling drums, and winding or lifting machinery—these names being in the order of suitability for polyphase working.

For drainage work it is preferable to employ fast running pumps direct coupled to the motors. The Riedler Express pump is a suitable make, being run at from 200 revolutions to 300

revolutions for small sizes, and at 120 revolutions to 150 revolutions for 200 HP. and 300 HP.

The frequency should be about twenty-five alternations per second; the rotor should be of as large diameter as possible, and as the clearance between rotor and stator is only from 1 millimetre to 2 millimetres (0·04 inch to 0·08 inch), great rigidity of construction is necessary.

If a fan is large enough to entirely absorb the power of one of the units in the central station, the necessary variation of speed may be obtained in the fan by altering the speed of the primary machine.

For winding drums, continuous current motors are preferable, and offer considerable advantages over steam, particularly as regards safety.

For mine locomotives, even with continuous current, two overhead conductors are necessary, and as another additional one does not much matter, especially when all the wires can be fixed to the roof of the mine, polyphase current is very frequently employed.

Iron and steel works and blast furnaces present a very favourable field for the application of electric power.

Blowing engines, driven by steam or by waste gases, will not, however, in the Author's opinion, be displaced by electric motors.

Rolling mills can very easily be worked by electric power if the rolls are three-high, but not otherwise.

Machines having a heavy fly-wheel action, such as shearing and punching machines, bending and straightening rolls, etc., have a special interest for electricians. One of the chief requirements in this case is that the motor must have enough slip, and this is obtainable with both continuous and polyphase current.

Direct driving of carrying rolls by electric motors is quite feasible, but requires special design of starting and reversing switch gear, the principal point being to have large contacts.

All the other machinery about blast furnaces and iron works, such as cranes, locomotives, etc., are quite suitable for the application of electric power.

The article extends to about forty pages and is profusely illustrated.

W. B.

Iron Direct from the Ore. A. Brand.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses-Sitzungs-Bericht, 1901, p. 197.)

The Author gives a short sketch of the history of the production of iron, of the early times when it was produced direct from the ore, the discovery of cast-iron and the introduction of the modern methods.

The old direct process was wasteful of both fuel and iron and was

only applicable to certain ores. On the contrary, the blast furnace is economical in fuel, and allows very little of the metal to run off in the slag, but the high temperature at the base of the furnace causes the iron, after having been reduced, to take up an excessive quantity of carbon and also such impurities as sulphur, phosphorus, etc.

The Author reviews the various efforts made in comparatively recent times to combine the advantages of the two processes—the methods of the brothers Siemens, Husgafvel, Conley-Lancaster, etc., and finally describes a process which gives great promise of overcoming the chemical difficulties, and, when the slag-producing impurities can be cheaply separated from the ore, of obtaining iron by the direct process with no more waste of fuel or loss of metal than now takes place in the blast furnace.

This process is covered by two patents owned by a company "Ferrum." The first patent is for a method of using carbonic oxide as a reducing agent on the pure ore, converting the carbonic acid formed by the reduction again into carbonic oxide and so on. In the repetition of this process all nitrogen is soon eliminated and no more heat is required than simply to effect the reduction. The second patent concerns the magnetic preparation of ore.

W. B.

A Combined Open-Hearth and Converter Process.

(Stahl und Eisen, vol. xxi., May, 1901, p. 524.)

At Nischne Salda on the Ural the pig-iron smelted from very pure magnetic ores with charcoal is so low in silicon that it is impossible to bring out the charge at the proper heat in the converter alone. It is therefore necessary to increase the initial heat in the metal by passing it through a Siemens regenerative furnace, where its temperature is raised to above 1,400° C. This shortens the time of blowing on the converter, and the charge is finished at a high temperature, the combustion of silicon going on through the whole period instead of being completed in the first few minutes. The nature of the changes will be seen from the following series of analyses :—

	Silicon.	Manganese.	Carbon.
Blast furnace metal	0·75	2·6	3·7
Metal superheated in Siemens furnace .	0·70	2·01	3·65
„ blown 3 minutes in converter . .	0·56	1·31	2·50
„ „ 6 „ „ „ . .	0·47	1·31	1·80
„ „ 9 „ „ „ . .	0·43	1·01	1·05
„ „ 12 „ „ „ . .	0·33	0·65	0·53
„ „ 14½ „ „ „ . .	0·026	0·31	0·25

When the silicon exceeds 1 per cent. rail crop ends or other steel scrap is added in the open-hearth furnace to reduce it to that amount as nearly as possible. The progress of such a charge is as follows :—

	Silicon.	Manganese.	Carbon.
Pig-iron, 2·6 tons	1·96	3·45	4·40
Scrap, 1·3 ton	0·021	0·20	0·45
Bath (calculated)	1·31	2·37	3·02
„ (actual)	1·18	1·72	2·28

During the superheating, therefore, the waste is principally confined to the manganese (0·64 per cent.) and carbon (0·24 per cent.), while the silicon is only slightly reduced (0·13 per cent.). In this respect the action of the Siemens furnace resembles that of the mixer. The further analyses of this charge made during the blowing are—

	Silicon.	Manganese.	Carbon.
Bath in Siemens furnace	1·18	1·72	2·28
After blowing 4 minutes	0·68	1·12	1·34
„ „ 8 „	0·35	0·80	0·70
„ „ 12 „	0·018	0·125	0·28
After addition of spiegel	0·02	0·275	0·33

When the silicon in the superheated metal amounts to 1·2 per cent. or 1·4 per cent., additions of 10 per cent. to 12 per cent. of cold scrap during the blow in the converter are necessary to control the heat developed. For the production of one ton of ingots by this method there are required 1·1 ton of pig-iron and 1·18 cubic metre of wood consumed in the gas-producers of the Siemens furnace.

H. B.

Definitions of Steel and Iron. AL. POURCEL.

(Baumaterialienkunde, 1901, p. 3.)

The Author in this Paper gives four views, which have been put forward at various times, of the best way in which to distinguish between steel and iron.

These may be put shortly as follows :—

(1) From the chemical standpoint steel has been defined as that compound of iron which contains a certain amount of carbon, and is particularly distinguished by its property of attaining great *hardness* by sudden cooling from a high temperature. Iron, on [illegible]er hand, is that ferrous compound which contains a smaller

quantity of carbon, but cannot be hardened by tempering. On the basis of this definition some untempered steels may be no harder than iron.

(2) The two names have been used to distinguish the metal which is produced as a spongy mass, and has immediately to be subjected to working to expel the slag, etc., from that which is produced in a fluid condition and requires no working, except to transform it from a solid mass into plates and bars and other useful forms. This use of the names is very widespread. Mr. Grüner has, however, objected to it on the ground that it is irrational to distinguish two materials by the methods of production without reference to the chemical composition.

(3) The distinction between iron and steel may be based on the property of the metals as regards hardening by tempering, that being considered as steel which is capable of being tempered, and that as iron which cannot be tempered.

The objection to this is that some modern steels, containing other elements besides carbon and iron, are made softer and not harder by sudden cooling.

(4) The fourth method of separating steels from irons is by the tensile strength, that above a certain strength being denominated steel, and that below this value as iron. This has been suggested by German authorities, but appears to be the most artificial of all.

J. G.

The Causes which Induce Brittleness in Steel. Ch. Fremont.

(Bulletin de la Société d'Encouragement pour l'Industrie Nationale, 1901, p. 254.)

It is well known that certain samples of iron and steel which give very satisfactory tensile tests will not stand bending on a cross-cut. For instance, a metal bar which under tensile strain had shown great elongation, a very decided reduction in diameter, in fact everything tending to excellent results coupled with a high tensile strength, may, when tested on a shallow saw-cut, by bending on itself, break under a load which represents a relatively small strength in the area affected by the bending tests. By way of illustration tests are given of two samples of steel at three different testing-stations, which, when exposed to tension in the direction of the fibre, broke at from 36·3 tons to 38·5 tons per square inch. The strength across the fibre, as determined indirectly by chisel-tests, was 354 tons per square inch. These samples came from different factories. A graphic diagram is given to show the behaviour under tension of the two samples of metal. Similar diagrams are given of four samples of the same description of metal, two of each quality, tested by bending with and across the fibre, having in all cases a saw-cut 0·039 inch wide and of the same depth on the under side. All the test-pieces were 1·18 inch *long, 0·39 inch wide* and 0·31 inch thick. The tensile strengths

under these circumstances varied from 1·27 ton per square inch to 6·03 tons, which are relatively poor results. Photographs are given of the four test-pieces enlarged to five times the size. Corresponding tests are given with enlarged photographs of parallel tests on another very similar sample of steel of a less brittle description, in which a stress of 13·33 tons per square inch was required to effect rupture under bending on a saw-cut. By reference to the photographs it is shown that in this latter set of tests the deformation was of a different character and that a larger area of metal was involved. The more brittle type of steel broke sharp across, starting from the saw-cut in all cases. It is pointed out that in certain qualities of steel not so brittle as to break down quickly under steady strain, the brittleness often becomes apparent under a smart shock, produced by the fall of a monkey, if the weight falls from a sufficient height. In the tests in question the brittleness did not manifest itself until the blow was given with a fall of 59 inches. By means of parallel lines ruled on the test pieces, the Author explains the nature of the deformations produced in the metal. Numerous diagrams and photographs are given in support of the Author's theory, which is that, subject to certain conditions imposed by the method of testing, any sample of steel is brittle or otherwise, in accordance with the extent to which the ratio of the elastic limit under tension to the elastic limit under compression is less or greater than unity.

G. R. R.

Basic Bessemer Steel.

(Zeitschrift des österreichischen Ingenieur- und Architekten-Vereines, 1899, p. 655 *et seq.*)

This abstract is from the debate on the report of the committee appointed by the Austrian Society of Engineers to consider the question of the suitability of Thomas or basic Bessemer steel for use in bridges. The published account of the debate extends to fifty-six pages of the journal.

Although steel had been used in the construction of bridges before the year 1880, it was decided by the Austrian Engineers in 1887 that they could not sanction its use as a material for their bridges, and it was only in the session of 1891–92 that specifications were framed providing for the use of Martin or open-hearth steel, but excluding basic Bessemer.

Mr. von Dormus regretted that the committee had confined themselves in their testing of the bars of the respective metals to the usual tensile tests, and advocated tests which would show the capability of a metal to resist shock, and also its degree of homogeneousness of structure. The drop bending test of nicked bars was, in his opinion, suitable for determining the shock-*resisting* qualities, and the microscopic examination of etched

sections a useful method for detecting undesirable irregularities of structure.

Mr. Emperger and others said that it was impossible to distinguish basic Bessemer from Martin steel, either by general appearance, fractured surfaces, colour, structure, strength, chemical analysis or microscopic examination, and they argued from this and also from the extensive use of basic Bessemer steel in Germany even for important structures, that this steel ought not to be restricted, for use in bridges, to have a lower limit of tensile strength than Martin steel, as was required by the report of the committee.

On the other hand, some of the speakers took exception to 27·3 tons per square inch as being too high a limit, and the reporter to the committee, after some discussion, accepted this view and agreed to 26·7 tons as the limit of tensile strength above which basic Bessemer steel was not to be allowed in bridge work.

Mr. von Dormus, in one of his several contributions to the debate, thought that the short time which elapses between the introduction of the raw metal into the converter and the teeming of the metal prevented the completion of the second stage of the basic Bessemer process, and that, in consequence, impurities were retained which might otherwise be eliminated. In the liquation that takes place during the cooling and solidifying of the metal, these impurities tend to concentrate in the higher and central parts of the ingot, and the two qualities of steel thus arising—edge steel and core steel—are encountered in all the rails, bars, etc., subsequently rolled, occasioning a degree of irregularity in quality and structure much greater than is met with in open-hearth steel. Owing to this he was of opinion that the ultimate strengths of pieces cut from the same bar might easily differ by more than the 4·2 tons per square inch, which was the limit set by the Austrian regulations for the material to be used in any one bridge.

Mr. von Dormus further communicated the results of his investigations into the behaviour of basic Bessemer steel rails.

He said that his studies on the Kaiser Ferdinand Northern Railway had led him to the conclusion that rail fractures could generally be traced back to a want of uniformity in the structure of the metal. The impurest metal, and that most wanting in homogeneity was in the centre of the rail head, and such metal being very weak against repeated stresses, or otherwise being very liable to fatigue, it frequently happened that a complete separation —rupture—was induced over a considerable area of the central portion of the head. This speaker had found old cracks in the centre of the heads of broken rails, which had, in his opinion, originated in the above manner.

Mr. von Dormus further said that these statements were not without application to bridge work because engineers had no guarantee that such slow processes of destruction might not go on *in the material of* their bridges, and, when some of the members

spoke against this view, he stated that, to his knowledge, cracks did actually occur in bridges, and had been observed in some considerable structures.

Other subjects discussed were the point in the somewhat irregular deflection-load diagram for a girder which was to be taken as the limit of elasticity for bending, the work of plastic deformation in girders, the use of mild and hard steels for bridges, etc.

J. G.

Effect of Bending and Straightening Cast-Iron. M. RUDELOFF.

(Zeitschrift des Vereines deutscher Ingenieure, 1901, p. 46.)

This is a communication from the Royal Mechanico-Technical Institute of Experimental Science of the result of experiments carried out. The Author refers to numerous authorities on this subject, which has an important bearing in the case of cylindrical vessels, especially steam boilers and gasholders.

Five sets of experiments were made :—

(*a*) Samples as received from the factory.
(*b*) Samples as received from the factory annealed.
(*c*) Bent cold, annealed, cooled, and then straightened.
(*d*) Bent and straightened cold, and then annealed.
(*e*) Bent and straightened cold.

The dimensions of the samples, mode of testing, angles through which bent, and full particulars of the experiments are given in two Tables, which furnish an exhaustive record of the results. The Paper is also illustrated by photographs, drawings, and diagrams.

W. A. B.

The Influence of Titanium on the Properties of Cast-Iron and Steel. AUGUSTE J. ROSSI.

(Engineering News, 30 May, 1901, p. 386.)

Titanium is found almost as abundantly as iron, and the ore occurs in mountain masses in Sweden, Norway, Canada, and several States of the Union. Pig-iron smelted from these titanic ores contains, generally, from 0·1 per cent. to 0·3 per cent. of titanium, frequently much less, and the pig is eminently a forge pig, and generally free from phosphorus. Experiments carried on at Adirondack are described. The average breaking load of a test-bar, 1 inch × 1 inch × 12 inches, between supports was 2,700 lbs. Adding 30 per cent. of nickel only to the normal mixture produced a very strong and tough material, bending at right angles without breaking. This ferro-nickel was added to

the normal mixture to produce metal with from ½ per cent. to 6 per cent. of nickel. At the same time with the test-bars chilled blocks were also cast. The addition of nickel strengthens the ordinary casting, but weakens the chill. Nickel and titanic pig added to the normal mixture increased the strength of the chill as well as that of the ordinary casting. Titanic pig alone produced first an increase of strength of the casting as well as of the chill, and when the percentage of titanic pig rose above 10 per cent., increasing up to 25 per cent., the strength of the ordinary casting was maintained, whilst that of the chill was greatly increased. As the titanic pig contains at most 0·2 per cent. of titanium, the metal contains really only traces of it.

Experiments were made with cast iron, treated by the addition of titanic alloys containing small quantities of carbon and silicon. Adding 4 per cent. of an alloy containing 10 per cent. of titanium increased the tensile strength of the metal 30 per cent. to 50 per cent., and the transverse strength 20 per cent. to 25 per cent. Experiments were also made with crucible steel. These were very limited in extent and not very conclusive, but as far as they went they showed that the influence of titanium on steel is very much in the same direction as on cast iron, also producing an increased ductility of the metal.

Some particulars are given of the methods adopted in carrying out the experiments and the preparation of the titanic alloys.

The Paper is illustrated by various diagrams.

C. H. M.

Official Tests of Gun Steel[1] *in France and in the United States.* S. Heryngfet.

(Mémoires de la Société des Ingénieurs Civils de France, 1901, p. 260.)

The example of the United States, the Author considers, might advantageously be followed in France, by modifying the mechanical tests so as to harmonize better with the continual progress of modern metallurgy, and to replace their empiricism and vagueness by really scientific and accurate methods.

In France the test-bars from land guns are tried by tension, and transversely by the blows of a falling weight. The gun-tubes are of mild cast-steel, forged, bored, tempered in oil, and annealed. On the tension-bars from the breech, tested prior to tempering, the test length measured is 100 millimetres (4 inches), while on those from the chase it is only 50 millimetres (2 inches); the conditions are subject to certain allowances. The transverse

[1] Specification No. 8 of the British Government for gun steel, issued in November 1886, is given in Minutes of Proceedings Inst. C.E., 1887, vol. *lxxxix. pp. 115–117.—A. B.*

tests are made on bars 30 millimetres (1·18 inch) square, laid on bearings 140 millimetres (5·51 inches) apart, with a weight of 18 kilograms (40 lbs.) falling from an increasing height of 1·0 to 2·5 metres (3¼ to 8¼ feet). For naval guns the conditions are somewhat different, while a bending test is added, which however is not always insisted on. For the transverse and bending tests the existing requirements have not been altered since 1879 for land guns, nor since 1882 for naval; both tests are considered by the Author to be too indefinite, often leaving it doubtful whether a gun should be accepted or rejected; and both alike are discarded by the United States. There too the tensile tests are much more complete and precise than in France, and the requirements are more varied and more stringent; if any lot of bars delivered for testing are rejected, the makers are not allowed to replace the individual specimens that have failed, but are required to send in an entire new lot for testing afresh.

Contraction of area at the fracture of a tensile test-bar is a most important criterion of the quality of a mild metal; if it is not less than 30 or 35 per cent. the bar will show an excellent fracture; and the converse is also true. In France, what is known as the Bourges classification of fractures is adopted, comprising no less than eleven varieties, which the Author severally describes; besides these there are numerous intermediate modifications. The contraction and the fracture concur in betokening the quality of the metal; a higher percentage of contraction corresponds with a more silky appearance of fracture, as illustrated by an elaborate Table of forty-six tests in the United States on bars cut from steel guns of 10 inches bore. But the same relation does not extend to the elongation of the test piece; poor elongation may accompany good fracture, and *vice versâ*.

The principal modifications desirable in the French tests of gun steel are summarized by the Author as follows. The transverse tests by falling weight and by bending should be abandoned, as too empirical, and as furnishing no precise or useful information. Even for small bores, tensile tests should be made on one or more pieces cut from each end of every component part of the gun—tube, jacket, or hoop; and the number of test pieces should vary with the bore. A minimum limit for strength should be imposed, and no margin should be allowed. The conditions should include a minimum percentage of contraction in area or of striction in diameter at the fracture. More complete information should be obtained about elastic elongation under different loads, about elongation corresponding with limit of elasticity, about permanent set beyond this limit, and about other deformations produced in testing the metal.

A. B.

New Alloys of Nickel and Aluminium. HÄNTZSCHEL.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses-Sitzungs-Bericht, 1901, p. 5.)

The difficulty in attempting to produce an alloy of nickel and aluminium arises from the great difference between the melting points of the two metals—1,450° and 600° C. respectively. If the experiment is made, it is found that the resulting alloy contains scarcely 2 per cent. of aluminium.

Now, a manufacturer in Berlin has introduced an alloy under the name "Nickel-aluminium." This is really an alloy of nickel, aluminium and copper, consisting for the most part, however, of aluminium, as is shown by its specific gravity—2·86.

The method of production depends on the fact that the melting point of copper is about a mean between the melting points of the other two metals, the aluminium first unites with the copper, thus preparing it to take up the nickel.

The process depends largely for its success on a special furnace designed by the manufacturer who has introduced the alloy, and also on the addition of certain fluxes. The complete explanation, however, is kept secret.

The alloy can be rolled into plates and bars, and the Author gives the average of six tests on such bars as showing an ultimate tensile strength of 25·9 kilograms per square millimetre (16·44 tons per square inch).

Another new alloy is "Minckin." It is similar to the so-called new silver, but appears to contain more nickel. Ordinary "new silver" contains about 26 per cent. nickel, and it has hitherto been difficult to get more than this in the alloy, owing to the development of gases in the mass. The furnace employed plays here again, according to the Author, perhaps the most important part.

"Minckin" is being largely employed on account of its resistance to the corrosive effects of weak acids and alkalies. The firm of Siemens and Halske use it almost entirely in the construction of the water meters sold by them.

The Author also mentions a new method of plating aluminium with other metals. The difficulty in attempting to plate, for example, aluminium on copper arises from the formation, during heating, of a film of oxide on the copper surface.

Even when this difficulty has been overcome the resulting compound plate has been brittle and liable to split.

The Wachwitz method overcomes all these objections by first forming a thin skin of copper-aluminium-bronze on the copper plate, preparatory to the actual plating process.

The same method is applicable to iron, and the Author suggests the construction of ships having plates with iron surfaces and aluminium body.

W. B.

Nickel Alloys. Dr. H. Wedding.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, 1901, p. 143.)

At a meeting of the Society, Dr. Wedding gave a short address reporting progress in connection with the work of the committee which had been appointed to investigate the production and properties of alloys of nickel.

Results obtained with iron-nickel alloys had already been published.[1]

The work on these was still being continued and micrographical analysis had been added to the previous methods of investigation.

The alloys of the four elements—iron, nickel, manganese and carbon—had been taken up, but the attempt to produce them had led to a most surprising outcome.

The elements were weighed and the alloys prepared and cast into blocks in the usual manner, but when these blocks were analysed the manganese seemed to have mysteriously disappeared, the percentages did not all correspond with the proportions originally weighed out. There were twenty-four casts in all and in some of these instead of 0·5 per cent. of manganese there was on the average only 0·15, in others instead of 1 per cent. there was only 0·33.

The disappearance could not be accounted for, but in order to produce the desired alloy it is proposed to melt the manganese first and then introduce it into the mixture of the other metals.

Tables of analysis of the alloys which so much miscarried form part of the Paper.

W. B.

Distribution of Ice and Conditions of Navigation on the Sea Route to Siberia. A. Varnek.

(Morskoi Sbornik, March, 1901, p. 63.)

The object of this article is to assist in solving the problem of the sea route to Siberia. The greatest obstacle is the ice, of the distribution and movements of which hardly anything has been published till quite recently. The proper route has been assumed to pass through the Kara Sea. Vessels have from time to time got through without encountering ice; at other times impenetrable ice has stopped them. Already in the sixteenth and seventeenth centuries Russian sealing vessels from Archangel and Kola went to the Kara Sea and found their way to the mouths of the Obi and Yenisëi. In 1760 a Russian sealer sailed round the North of Novaia Zemlia. Hardly any records were left; the route to the Siberian rivers was

[1] Minutes of Proceedings Inst. C.E., vol. cxlii. p. 432.

forgotten and the Kara Sea was considered impracticable. Only in the second half of last century have voyages to the Kara Sea been recommenced. The first successful voyage through the Kara Sea to the Obi was made in 1869, and since then every year sealers—principally Norwegian—have found their way through the Kara Sea or round the North of Novaia Zemlia or both. The first properly recorded voyage was that of Captain Wiggins in 1874. All steamers have hitherto gone by one of the straits through Novaia Zemlia, none have gone round the north of the islands. Numerous particulars are given in much detail of observations made on many voyages. There are no data to show that the southern route through one of the straits and the Kara Sea is better than that round the North of Novaia Zemlia. On the contrary, recent data go to show that the northern route is at least as good as and probably better than the southern one. The cold is always more intense near land than in the open Arctic Ocean, and the Kara Sea being landlocked except when it opens into the Arctic Ocean in the N.E. is colder than the ocean itself. Approaching from the west, the isothermal lines turn almost due north on approaching the islands, and probably pass round their northern end. The warmer waters of the gulf stream sweeping round the North Cape are deflected northwards by Novaia Zemlia. The temperature of the air in the Kara Sea is about 18° F. lower than that in the Arctic Ocean to the west in winter, and about 8° in summer. The numerous rivers flowing, some into the Kara Sea, some to the west and some to the east of it, make the water of that part of the sea fresher than it is in the open ocean, hence the water freezes sooner. The prevailing north-east winds set the ice into the Kara Sea and prevent its getting out again. All these circumstances point to the conclusion that there should be more chance of finding open water round the north of Novaia Zemlia than in the Kara Sea, and all recent experiences go to show that such is the case. In the last 5 years the passage round the north of the islands has been clear whilst the straits to the Kara Sea have frequently been blocked till late in the autumn. But many more observations are required before one can come to a definite conclusion on this point.

Many of the particulars of the voyages and numerous observations of temperatures are tabulated, and some of the principal voyages are illustrated by two maps.

C. H. M.

Examination of Spring Water. FÉLIX MARBOUTIN.

(Mémoires de la Société des Ingénieurs Civils de France, 1901, p. 367.)

Besides depending upon chemistry, bacteriology, geology, and medicine, for determining whether spring water is suitable for drinking, it is necessary to trace the route which the water has

followed for reaching the spring, and to investigate the opportunities of pollution it may have met with in its course. For this purpose must be ascertained the area of water-shed feeding the spring, and how the rain passes down through the subsoil and reaches the water-bearing stratum whence the spring issues. In the neighbourhood of the Avre water-shed,[1] from which is drawn a portion of the water-supply for Paris, the method successfully followed by the Author has consisted in pouring a solution of colouring matter into the ground successively at every spot where the surface water has been found to be making its way into the subsoil; and in then observing the time of the colour reaching the several springs and wells within range of the particular spot under treatment. The rate of flow through the water-bearing stratum is thus determined in a number of radiating directions, and is plotted in curves more or less normal everywhere to the several lines of flow; the name iso-chrono-chromatic has been given to the curves. They serve to indicate the relative importance of the different routes, along which a detailed examination is then made of the surface of the ground, and of all possible pollutions likely to contaminate the water. The rate of flow per hour has been found to range from 47 to 600 metres (150 to 2,000 feet); in chalk it is usually from 120 to 150 metres (400 to 500 feet). The colouring matter preferably used is fluoresceïn ($C_{20}H_{12}O_5$),[2] in the form of a solution containing 100 grams per litre of water; that is, the fluoresceïn is one-tenth of the weight of the water. The quantity of fluoresceïn poured into the ground is about 300 grams (0·66 lb. in 6·6 lbs. of water, say three quarts of solution); from 300 to 700 grams (three to seven quarts of solution) suffices for reaching springs not more than 5 kilometres (3 miles) distant. It is poured steadily, and not faster than 300 grams (three quarts of solution) per hour; sometimes twice or even thrice as slowly. Along with it a quantity of water must be poured down, sufficient to give the necessary head for ensuring its becoming diffused through the water-bearing stratum. Its distinctive tint is still just visible to the naked eye in a solution of 1 in 10 million; but by means of the Trillat fluoroscope 1 in 2,000 million is detected, and the Author has himself detected one-fifth as much. He gives a list of nine commercial varieties of fluoresceïn employed in his researches, and of their colours, and of the limits of dilution at which their colouring effect can be detected by the fluoroscope. The value of the ground as a filter for the water passing through it is ascertained by pouring down a fermenting solution, such as one containing yeast, and observing whether any of the germs reach the springs. In engineering, the plan lends itself to a variety of purposes: for laying out the drainage of irrigated land, for examining water from mines, and for investigating strata yielding mineral waters

[1] *Minutes* of Proceedings Inst. C.E., 1900, vol. cxl. p. 336.
[2] *Watts' Dictionary of Chemistry*, by Muir and Morley, 1889, vol. ii. p. 557.

or petroleum. Besides the causes of pollution, and the modes of determining the quality of water and its purity, the Author reviews its hardness, and the several ingredients usually met with: chlorine, organic matter, nitrites, nitrates, ammonia, oxygen, bacteria, and others.

A. B.

The Water-Supply of the Industrial Districts of Upper Silesia. Dr. Bloch.

(Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, vol. xxxiii., 1901, p. 223.)

A history is given of the movement which brought about the provision of a public water-supply for the dense industrial population of Upper Silesia. The Author traces the steps taken even so far back as 1826 by the municipal authorities of the town of Beuthen to improve their supply and alludes to various later complaints of scarcity of water which led in 1865 to the construction of water-works. It is shown how these local works were from time to time extended. Subsequent enquiries by Pistor, Hulwa and Salbach mark the steps taken to obtain supplies for a wider area from various sources, until the last-named engineer succeeded in October 1879 in finding water of good quality in two borings, driven to a depth of 235 yards, not far from the village of Zawada. These wells yielded 6,600,000 gallons per diem of water, which from the chemical and microscopic point of view was quite satisfactory, and the temperature was 11° C. By means of a section the Author indicates the various strata passed through. Figures are given of the population and the number of head of cattle in the districts to be served. In 1878 the population was 237,315. It was estimated by Salbach that an additional volume of 8,800,000 gallons of water daily was required, and after an examination of the various supplies it was decided to make use of the water discharged by pumping from the Friedrich mine, which amounted to 5,500 gallons per minute, and would thus furnish nearly all that was needed. The cost of the pumping station, supply mains, etc., for the entire scheme amounted to £375,000. An account is given of the gradual extension of these works with the additional supply from the Rosalie mine which now serve for a population amounting, at the last census in 1899, to 582,000. A plan is appended showing the principal mains and the three chief sources of supply.

G. R. R.

The Distribution of Germs by Ordinary Air-Currents.

Dr. R. F. HUTCHISON.

(Zeitschrift für Hygiene, vol. xxxvi., 1901, p. 223.)

Though it is impossible to doubt that dwellings are exposed to the risk of a whole series of infectious diseases due to the entrance into them of infinitesimally small particles of dust and moisture laden with germs, it is difficult to say how often this may occur. A certain number of observers have made enquiries bearing upon this question, but the subject is far from being exhaustively cleared up. The Author refers to the investigations of Mareau and Miquel out at sea to indicate the distances to which germs may be transmitted in the air under favourable circumstances, but, as he points out, the conditions are entirely different on land, where the houses are near together. He set himself to determine the extent to which it is possible for germs to be conveyed from floor to floor or from room to room in a house by means of window-openings, crevices and keyholes, or to find their way by means of chinks into drawers, cupboards, books and papers. He also made experiments as to the vitality of germs which have once been deposited and concerning the extent to which they may be stirred up and spread abroad by treading about on floors and by brushing, sweeping, dusting clothes, etc. He alludes to the results already recorded which relate to this question, and he explains how his test-substances were prepared and the method adopted for spraying the prodigiosus germs used by him. By reference to a block-plan of the Hygienic Institute at Göttingen, the Author describes the position of the various rooms and corridors employed for his experiments. A detailed account is given of the procedure in the various tests. In the case of the leaves of an open book and of letters transmitted through the post, he was able to show colonies of the germs, though in a letter which was six days in the post, having been sent from Göttingen to Scotland and back, the germs had lost their vitality. On this point he states that while it is just possible for disease-germs to be conveyed by a letter, it is highly improbable that this should occur. In addition to indoor experiments he conducted a number of tests in the open air, which are explained by means of a series of diagrams. Certain of the gelatine plates in the open, even 656 yards distant from the spraying station, contained colonies of prodigiosus.

G. R. R.

Mechanical Illustrations of the Laws of Electricity.

M. MÖLLER.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, 1901, p. 129.)

The apparatus described in this Paper has been designed to assist to a clear comprehension of the relations between electromotive force, strength of current, resistance, potential, etc.

The place of the electrical current is taken by a stream of air or any suitable gas, the motion being produced by the weight of an inverted vessel enclosing air and floating on water. A glass tube extends from the enclosed air-space downwards through the bottom of the vessel containing the water, and from here it is continued by flexible tubing through resistances, etc., and is finally led in at the top of the same vessel from which it started.

The glass bottle containing the water with the air-holder floating on the surface constitutes an element. Two or more elements can be grouped in parallel or in series, the results corresponding exactly with the electrical phenomena. The current is measured with the aid of a small column of water moving in a slightly inclined capillary tube.

The velocity of motion of this column is the measure of the current strength.

The work done by the current is measured by having in the circuit a glass tube with a vertical step, through which the above-mentioned column of water is forced. The pressure due to the weight of a column of water of a height equal to the rise of the step in the tube is a measure of the "counter electromotive force."

The voltmeter consists of a barometer tube with equal legs, one of which is open to atmospheric pressure, and the other connected with the circuit. The tube is half filled with water, the difference of level in the two legs being a measure of the "voltage."

The resistances are constituted by bent tubes filled with dry sand.

The Author describes a number of experiments with various arrangements of the different apparatus, each designed to illustrate a particular electrical phenomenon or law.

W. B.

Electrical Works at Abbazia.

(Zeitschrift des Vereins deutscher Ingenieure, 1901, p. 125.)

The power-house is on the sea-shore 1 mile from the distributing station. On the ground floor are the engines, and in the first storey the offices, store-rooms and men's quarters. The square

chimney, 130 feet in height and 5¼ feet internally, has false windows and a wooden gallery with slate roof.

The engine-house is 65 feet by 41 feet, containing four 100-HP. engines. The boiler-house, 46 feet by 41 feet, is furnished with two Tischbein boilers, each having a heating surface of 1,292 square feet. Coal is unloaded directly from the ships. A tank holding 3,532 cubic feet catches the rain-water from the roofs and supplies the loss by condensation. Each of the engines drives two dynamos of 36 kilowatts.

The accumulator battery consists of 180 cells, supplying 600 ampere-hours and capable of feeding 1,200 glow-lamps of 16 candle-power for 3 hours.

There are 26·5 miles of underground cable and 12·4 miles of overhead wires.

At the end of 1899 there were 5,171 glow-lamps, and provision has been made for 1,000 more for the year 1900.

W. A. B.

Wireless Telegraphy. O. Rochefort.

(Mémoires de la Société des Ingénieurs Civils de France, 1901, pp. 396–405.)

The transmitter and receiver devised by the Author are applications of electric currents oscillating with high frequency. The transmitting apparatus comprises a twelve-cell battery of accumulators, supplying the main current to an intensifying transformer of high voltage; an intermediate oscillating mercurial interrupter, actuated by a two-cell battery independently of the main current; a condenser with three adjusting pins, having its two terminals connected to opposite sides of the interrupter; and on the circuit of the main current a non-periodic ampere-meter, together with a manipulator for signalling on the Morse plan. The poles of the transformer are each tipped with a gilt ball. The distance between the balls can be increased or diminished at pleasure, and through it shoot the Hertz sparks. One pole is earthed, and to the other is attached the vertical transmitting conductor, suspended from the top of a mast.

The twelve-cell battery for the main current has a capacity of 100 ampere-hours, and can give a discharge for 10 hours; the consumption is from 6 to 9 amperes at 24 volts. The transformer is upright, having a single pole. It is intensifying because the secondary winding is formed of a double slab, by winding together two wires joined only at their exit and entrance. The double coils are wound in successive layers, starting from the centre of the ring. Great difference of potential is thereby obtained at the two terminals; the tension at the pole connected with the centre of the ring is insignificant compared with that of the pole connected with the circumference. By the earthing

of the low-tension pole the spark is not diminished either in length or in volume; it seems whiter and drier. This new mode of winding can be carried out only with the pasty insulating material used for these transformers, which give a spark eminently suitable for wireless telegraphy. The distance between the gilt balls is 0·3 metre (12 inches); but the spark would shoot across a gap of 0·5 metre (20 inches), if they were so far apart. The transformer is 0·85 metre (34 inches) high and 0·28 metre (11 inches) diameter. By its means Messrs. Tissot and Jéhenne of Brest have communicated between ships 80 kilometres (50 miles) apart, with a conducting wire 24 metres (79 feet) high.

On board ship the dipping rod of the mercurial interrupter is actuated by a small independent electric motor; and the mercury in the cup is covered by a layer of petroleum, within which the current is broken. The three adjusting pins of the condenser give a range from 30 up to 100 total capacity. The manipulator is an upright conducting rod, tipped with an insulating knob, and when depressed touching the rim of a disk of red copper, which lies in the bottom of a copper cup filled with petroleum; when wear occurs, the point of contact is changed by rotating the cup. The vertical transmitting conductor is a slender rope about 8 millimetres (0·3 inch) diameter, composed of five or six copper wires, and covered with gutta-percha. It is hung from an insulator, consisting generally of an ebonite stick, 0·5 metre (20 inches) long and 0·2 metre (8 inches) diameter, capped by a porcelain bell. With conductors 35 metres (115 feet) high, distinctly oscillating sparks can be got 0·09 metre (3½ inches) long. The bottom end of the conductor is furnished with a socket, fitting upon a pin at the high-tension pole of the transformer.

For signalling, the interrupter is set to work at from 14 to 30 strokes per second, the gilt balls are fixed from 0·02 to 0·09 metre (0·8 to 3·5 inches) apart, and the knob of the manipulator is depressed and held down for shorter or longer periods corresponding with the dots and dashes of the Morse alphabet. During each depression sparks and oscillating discharges are produced every time the dipping-rod of the interrupter comes out of the mercury; the discharge is practically instantaneous, and is made up of ten to fifty sparks. The motion of the interrupter is so rapid that it looks absolutely stationary when lit up by the sparks it produces; the only movement visible is the slow and slight oscillation of the surface of the mercury into which the rod dips.

The receiving apparatus comprises a vertical collecting wire, like the transmitting conductor; a coherer of soft-iron filings, placed in the circuit of a highly sensitive relay with a single cell; also a double-acting decohering hammer, and a Morse receiver, both actuated by electro-magnets, which are coupled in parallel, and receive their current from a three-cell battery through the contact made by the relay. The collecting conductor is connected

with one end of the coherer, of which the other end is earthed; each connection is made by a socket fitting on a pin. Hence by disconnecting both from the coherer, and connecting them with the transformer of the transmitter, the same vertical wire can be utilized alternately for transmitting and for receiving. In the French navy the Claude relay is used with advantage, having a single contact, which works well with this receiving apparatus. The two pole-pieces or electrodes in the glass tube of the Tissot coherer are of soft iron, 3 to 5 millimetres (0·12 to 0·20 inch) diameter, with their inner ends bevelled symmetrically and fixed 0·8 millimetre (0·03 inch) apart where nearest; the intervening space contains filings to a depth of 1 millimetre (0·04 inch), when the tube is horizontal and the pole-pieces are nearest on its lower side. The vacuum in the tube is maintained on Geissler's plan. In the Author's coherer the soft-iron pole-pieces are annular; one is soldered to a platinum wire sealed into the nearest end of the tube, and encloses an ebonite or other insulating cylinder; the other encloses a copper cylinder. Through both cylinders passes a central copper rod, soldered to a platinum wire that is sealed into the other end of the tube, in which is placed a stick of carbide of calcium to keep the vacuous interior dry. The minute space between the electrodes, whose facing ends need not be bevelled, is filled with soft-iron filings up to the level of the centre rod. The decohering hammer, actuated by an electro-magnet and a spring, strikes the coherer tube both in rising and in falling; the double action, which is the Author's device, ensures decohering more completely. The Morse receiver is of ordinary kind, delivering the tape at the rate of 0·6 metre (2 feet) per minute. Assuming the resistance of the coherer to be 15,000 ohms when decohered, and to fall to 1,000 when cohered, the relay is so adjusted that at the higher resistance the voltage of its single cell is not sufficient to pass through the coherer and complete its circuit. But a Hertz wave received by the collecting conductor coheres the iron filings, enabling the coherer to complete the relay circuit, and thereby to close the contact which sends the three-cell current to the electromagnets actuating the decohering hammer and the Morse recorder. By means therefore of the Hertz waves, every signal issued from the transmitter is communicated to the receiver, and here recorded correctly.

Though coherers made with filings are most used, as being the only kind that are trustworthy enough, there are others decohering of their own accord, called "auto-decoherers," which dispense with the single-cell relay, the decohering hammer, and the Morse recorder; the signals are received by the ear through two telephones. Self-acting decoherers, which appear to have originated with the late Professor D. E. Hughes, the inventor of the microphone, are generally made with charcoal pole-pieces and charcoal *powder*; or else with german-silver or other metallic pole-pieces, *and* charcoal powder more or less coarse, or steel powder. But

the difficulty is to get sensitiveness in combination with a uniform difference between the resistance of coherence and that of decoherence.

A converse plan is that of Messrs. Mengschwender and Schafer, in which a bit of silvered looking-glass is wrapped with wire made from razor-steel. If it is mounted as a coherer, in which the pole-pieces or electrodes would be the opposite sides of the silvering, and if the surrounding air is kept moist, the current is always passing, and the resistance is about 50 ohms. Under the action of the Hertz waves, the resistance suddenly rises to 8,000 ohms. This contrivance, hence called an "anti-coherer," has been practically employed by Mr. Belenschaffer, apparently with good results.

The Hertz waves, extending in circles from the vertical transmitting conductor, appear to follow planes parallel to the earth's surface. They are less easy to send in any particular direction than those of sound; their great length, from 0·75 to 4·50 metres (2½ to 15 feet), renders it impracticable to construct a bell-mouth or trumpet large enough. Syntony or tuning of the receiver, so as to vibrate in accord with a particular transmitter only, has not proved satisfactory in practice at present. The signals received are liable to be confused by parasitic vibrations. In order to ensure receiving only the most powerful, it is easy to eliminate the weaker by a suitable resistance-box interposed between the collecting conductor and the coherer.

A. B.

Effect of Lightning on Electrical Power Mains. Aug. Larson.

(Teknisk Tidskrift, Stockholm, 10 November 1900, p. 137.)

On 23–24 August 1900 an extraordinary thunderstorm occurred on the line of wires conveying power from the generating station at Vestgötehyttefors to the Striberg mining district in western Vestmanland, a distance of about 11½ kilometres (7⅛ miles). Strangely enough the effects did not attract attention till 20 September, when a minute examination was made of the entire line. The report of the Author, who is managing director of the Northern Mining Electric Company, states that the power transmitted is about 500 HP., with a potential difference of 6,000 volts per phase, equivalent to about 10,500 volts at the dynamos. The lightning appears to have struck the line at the fifty-eighth pole from the power station. It first struck a pine growing on an eminence about 11 metres (12 yards) from the line; and, following one of the roots, it trenched the ground open to the prop of pole 58. Splitting the prop, it ran up one side of the pole to the lowest conducting wire, along which it discharged

at several of the poles in either direction, as far as Nos. 51 and 98, splitting and splintering them with varying violence. Pole 58 was shattered above the prop, and its splinters were sent flying to a distance of more than 20 yards. The insulator of the middle wire remained unscathed; those of the two other wires were found hanging from their wires; one of them was split at bottom, and had lost its bolt. The pole was charred across in streaks, where the wires had touched it as they swayed in the wind. In spite of all the damage done, the line continued working without interruption, and no more than three of the poles had to be replaced. The highest point of the line is at pole 72, where it crosses an almost bare ridge; this pole, standing in a marsh, was broken across in the middle, and thence splintered downwards. At the power station the cast-iron casing, fencing the bottom of the lightning conductor, was broken in two, the volt meter was destroyed by the burning of its coil, a spark shot across from the lighting wire to a telephone wire 40 metres (44 yards) distant, the telephone coil was somewhat burnt, and the steel magnet of the call-bell was destroyed. The engines were stopped as speedily as possible. At the receiving stations no inconvenience was occasioned. About 1 kilometre ($\frac{5}{8}$ mile) from the power station a flash was seen approaching it, which swept along over the wires like a brush, and vanished at the lightning conductor nearest the station.

A. B.

Smell in Accumulator Cars.

PAUL BERGSØE, J. B. BRUUN and C. KJÆR.

(Ingeniøren, Copenhagen, 1900, p. 350 *et seq.*)

In the accumulator cars on the Copenhagen tramways there has often been so disagreeable a smell that passengers have got out to escape it. Enquiry being made as to the probable cause, the following explanations were volunteered by electrical engineers.

While no inorganic compound having the same smell can be formed from the contents of the accumulators, Mr. Paul Bergsøe points out that this is the smell emitted by deal which has been dipped in dilute sulphuric acid and laid aside for a time. It must therefore be due to the destructive action of the acid upon the resinous or other residue of the sap. The hydrogen liberated in charging the accumulator cells bubbles up to the surface of the dilute sulphuric acid; and the bubbles in bursting scatter microscopic drops of acid, which remain floating in the air for a length of time. The air thus impregnated attacks the woodwork of the chamber containing the battery, and also of the car, to the whole of which it has free access when the seats are turned up for *charging* the battery placed beneath them. For obviating the

nuisance it is suggested to ventilate the battery chamber, and to make it accessible from the outside of the car, instead of from the inside.

The same cause is assigned by Mr. J. B. Bruun, who adds that, when the charging of the accumulators is approaching completion, the evolution of hydrogen becomes so violent as to give the liquid the appearance of boiling; a larger quantity of acid is thereby sprayed into the air. In the accumulator cars for lighting the trains on the Danish State Railways the cells are set up in leaden trays, from which is provided an outflow. On an electric tramway worked experimentally for several years in Hagen, it was endeavoured to get rid of the strong smell in the cars by exhaust ventilators drawing from the accumulator chambers under the seats; but they were not powerful enough to prevent some of the acid fumes from penetrating into the cars towards the end of the charging. To cover all the accumulators with air-tight leaden hoods, and draw off the vapour through a common outlet by a suction ventilator, would render examination of the battery difficult; and glass covers would be liable to break. In accumulators made at Kalb, near Cologne, the fumes are trapped in a thin india-rubber ball overhead, whence the acid trickles back into the accumulator.

Both hydrogen and oxygen, according to Mr. C. Kjœr, are given off from an accumulator towards the end of the charging, nearly in the volumetric proportion in which they form water; and both are impregnated with acid. A small quantity of oxygen also comes off as ozone, which has the peculiar penetrating smell noticed in accumulator cars. When the charging and discharging of the accumulators follow each other in quick succession with a strong current, the temperature in the battery chamber rises considerably above that of its surroundings. On the Berlin and Charlottenburg tramway it is always over 30° C. or 86° F. and in the warm season from 60° to 65° C., or 140° to 150° F., has been registered. Acid settling upon the sides and bottom of the chamber soon becomes concentrated by the combined heat and draught, and attacks wood so strongly that in a couple of months it looks as though it had been partially charred throughout its entire thickness. However carefully the chambers are protected with acid-proof linings of insulating material, the acid penetrates through the minutest crevices; when once it reaches the wood, there is no stopping its destructive action and the consequent liberation of odorous organic compounds. The ebonite cells ordinarily used for tramway batteries can also contribute to the smell; their surface is attacked by ozone, and in time they themselves become hard and brittle. Hanging the battery under the car, whereby the objectionable smell would be completely obviated, has been tried elsewhere, but abandoned, owing to want of sufficient room for battery and motors together; moreover the motors might then be attacked by the acid, whilst the battery

would be inaccessible for examination after charging, unless complicated and expensive arrangements were specially made. As an inside battery requires its cover removing for every charging, it is scarcely possible to prevent some escape of air impregnated with acid; but the nuisance may be so far diminished as to be insignificant. Only ten to fifteen minutes are allowed for charging the North Bridge tramcars in Copenhagen, and the charging must therefore presumably continue almost up to the time of starting; whereas the charging ought to be finished, and the battery chamber to be shut off from the car, some minutes before starting, so as to allow time for the air in the car to get fresh. Blowing air through the battery chamber is the wrong way of getting rid of the vapour, which ought to be exhausted by suction. In Berlin, where there has been some talk of abandoning accumulator tramcars, the reason would not be the smell caused by the acid, but rather the serious interruptions of the heavy Leipziger-strasse traffic by last winter's frost and snow, when thrice the usual power was required. This section of line is worked on a mixed plan of accumulator-cars and conductors, which allowed the former to transfer part of their charge to cars wanting more power than the conductors could supply; whence the tension in the batteries frequently fell to 100 volts below their normal, and inconvenient stoppages resulted. In Hanover the mixed plan has been in operation for some years with entire satisfaction.

A. B.

Oudin Double-Pole Resonator. O. Rochefort.

(Mémoires de la Société des Ingénieurs Civils de France, 1901, p. 394.)

In Dr. Oudin's single-pole resonator, two square condensers or Leyden jars are used, each having its inside armature or coating connected at top with a conducting rod, which is surmounted by a metal ball, and is connected with one of the poles of a high-tension Rochefort transformer supplying the electricity. The outside armature or coating of one of the two condensers is connected with one extremity of a solenoid, and that of the other condenser is attached to an intermediate point of the solenoid helix. When the two balls of the condensers are brought near enough for an oscillating discharge of sparks to take place between them, synchronous oscillations are produced in the primary coils of the solenoid, that is, in those which are between the attachments of the two condensers. Synchronous oscillations in the contrary direction are induced through the rest of the solenoid; and from its free pole issues an oscillating efflux, alternately positive and negative. For a given expenditure of *electricity* the efflux attains a maximum when the intermediate

point of attachment to the solenoid occupies a certain position, dependent upon the capacity of the condensers and the conditions of the solenoid, but independent of strength of charge and distance between balls. In a powerful single-pole resonator it may extend to a distance of 0·12 metre (say 5 inches). It is of the same sign, positive or negative, as the opposite end of the solenoid.

In a double-pole resonator, made by placing a duplicate solenoid alongside the first, the discharges from the two poles would not synchronize unless the two solenoids balanced each other perfectly, which is a condition that would be difficult to realize in practice. The double-pole action is therefore obtained by duplicating the Leyden jars, and coupling their inside armatures in pairs; there are then two resonators, controlled still by a single pair of sparking balls, while their two primary circuits have no point in common. This arrangement is found entirely satisfactory by Dr. Oudin, of Paris, who uses it for the treatment of tuberculosis, as also does Dr. Doumer, of Lille. The patient holds one of the solenoid poles, and the efflux is given off from the other by a metallic brush. The power is adjusted to his capacity by shifting the intermediate point of attachment to one of the solenoids. The efflux can be disseminated through a distance of 0·7 metre (28 inches); and is estimated to be ten times as powerful as from the ordinary single-pole resonator, for equal first cost. The double-pole instrument is now being used by many electro-medical practitioners, for skin diseases and affections of the nerves, as well as for tuberculosis.

A. B.

The new Swiss Law concerning High- and Low-Pressure Electrical Installations.

(Schweizerische Bauzeitung, 1901, p. 14 *et seq.*)

The new Swiss law which will come into force this year is of interest to electricians, as the only previous Act dealing with the matter was one of 1889, concerning telegraph and telephone lines, to which certain clauses had been added applying to high potential installations at the request of the Swiss Electrotechnical Society. The same society issued, in 1896, a set of rules for the construction and working of high potential installations, and afforded protection to the public—a matter not dealt with in the Act of 1889.

Already in 1888-89 it had been strongly recommended that a metallic return should be used for telephones, and the public at one time demanded that all cables carrying heavy currents should be buried, while the Government should have the sole right to use aerial conductors and earth returns. In 1897 the Swiss Society appointed an inspector of their own, and after a time he obtained the recognition of the Government. The Author gives an account of the steps which led to the introduction of the present Act,

one of the most important being the destruction of the Zurich Telephone Exchange by fire. In the first section low and high pressures are defined as follows:—low-pressure installation are those in which, under normal conditions, currents are not used which are dangerous to life; and high-pressure installations those in which currents which may be dangerous to life are employed. No numerical definitions are given. Another article empowers the Swiss Government to see that in every installation, whether of high or low pressure, that proper precautions are taken for the avoidance of danger. No attempt has been made to import technical definitions into the Act, as the Author points out that these will vary as the science progresses, while the Act is intended to give general and sufficient powers to the Government to ensure the safety of persons and property. One clause of the Act provides that where high potential supply is to be used the cost of adding a metallic return to the telephone service is to be borne by the undertakers of the new enterprise; but the National Council altered this, and while requiring the high potential enterprise to properly protect the public wires from injury, specially states that the Government is liable for the cost of adding the metallic return. A small Commission of seven representatives of electro-technology will be entrusted with the work of administering the Act. The Author then proceeds to analyse the separate clauses of the Act.

E. R. D.

Materials at the Paris Exhibition. M. Rudeloff.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, 1901, p. 37.)

The exhibits of machines for testing the strength of metals by Olsen and Co., Fremont, Le Blant, Digeon and Son, Delaloe and others are described and illustrated, as also various machines for testing limes, cements, stone, textile fabrics and paper. Incidentally the ratio of the shearing strength of materials to the tenacity is shortly discussed. Fremont's experiments gave the unusual proportion of 1 : 2, and Prof. Rudeloff, throwing doubt on the reliability of Fremont's methods, gives the conclusion of his own experiments as showing that for iron and copper, the shearing strength is three-fourths of the tensile strength, and for brass two-thirds. Considerable space is given to the description of the exhibits of iron alloys, particularly nickel and chrome steels, with numerous Tables of tests. One Table shows that the strength of a lapped riveted joint, when the plates and rivets are 5 per cent. nickel steel, is more than double the strength of the same kind of joint with plates of ordinary steel and rivets of iron. Tests of pieces cut from a 3 per cent. nickel steel crank shaft gave the yield point *at 50* kilograms per square millimetre (31·75 tons per square

inch), the ultimate strength 66 kilograms per square millimetre (42 tons per square inch), and the extension 19½ per cent. on 100 millimetres (4 inches). A gun steel with 5½ per cent. nickel gave the yield point at 60 kilograms per square millimetre (38 tons per square inch), the ultimate strength 80 kilograms per square millimetre (51 tons per square inch), the extension 20 per cent. on 50 millimetres (2 inches) and the contraction of area 45 per cent. A steel with 11 per cent. nickel, also from a gun, had an ultimate strength of 161 kilograms per square millimetre (102 tons per square inch). The strength of wire made of steel with 25 per cent. nickel is given at 210 kilograms per square millimetre (133 tons per square inch). Of annealed chrome steels, that with 15 per cent. chromium has the highest ultimate tensile strength, 71·4 kilograms per square millimetre (45·3 tons per square inch). The same steel, when tempered, had a tensile strength of 91·5 kilograms per square millimetre (58 tons per square inch).

The Paper is accompanied by 8 Plates.

W. B.

Composite Timber Columns. HALBERT POWERS GILLETTE.

(Engineering News, 13 June, 1901, p. 439.)

Smith's formula used to be applied to composite columns with a factor of safety of 6, assuming the strength of a built-up column to be the same as that of a solid column of the same size. As a result of Professor Lanza's experiments, some now consider that when a column is made up of a number of sticks bolted together, each stick should be considered as a separate column and its strength calculated accordingly, the strength of the whole being the sum of the strengths of the separate pieces. In this case a factor of safety of 4 is used, and the result is much the same as with Smith's formula and a factor of safety of 6. The first method makes the strength too great, the second too small. From formulas in "Modern Framed Structures" the formula for the lateral deflection of a column, in inches, at rupture, is deduced thus: $\Delta = \frac{0{\cdot}03\,l}{E} \times \left(\frac{l}{d}\right)^3$, where l = length of the column, and d = least side of rectangular column, both in inches, and E = modulus of elasticity.

When $l = 10$ feet or under, bolts cannot materially increase the resistance to crushing in bridge structures. But in longer columns bolts will have the effect of making the built-up column equal in strength to a solid one. The greater the length of the column the less may be the ratio $\frac{l}{d}$ at which bolts may be considered as *rendering the built-up* column practically solid. A Table of lateral

deflections, calculated by the above formula, for white pine, is given for columns 10 feet long, and for varying ratios of $\frac{l}{d}$. From this Table Δ is easily calculated for any other length of column.

C. H. M.

Fire-Retardant Treatment of Woods.

(Engineering News, 27 June, 1901, p. 459.)

This is taken from a Committee Report presented to the National Fire Protection Association at Chicago. The subject is divided into two parts:—(1) Fireproofed wood, that is, wood chemically treated so as to render it practically non-inflammable throughout; and (2) Fire-retardant coatings for wood, such as paints, etc.

(1) There are only three processes in practical use in America for fireproofing wood throughout. The oldest has been in operation since 1895, when wood, prepared by this process, was first supplied for war-vessels to the United States Government. Most of the war-vessels since then and many large buildings have been fitted with this wood, which is prepared by the Electric Fireproofing Company by what is known as the Bachert process. In this process and in that used by the American Wood Fireproofing Company, the wood is first exposed to steam under light pressure, then to vacuum, and finally is impregnated with chemicals under high pressure. The third process is known as the Ferrel process; in this there is neither steaming nor vacuum, only impregnation by chemicals under very high pressure. In all cases the wood is afterwards kiln dried, and then weighs about 10 per cent. more than before treatment. The transverse strength is increased in white pine and diminished in yellow pine; the compression strength is diminished in both cases, and the tensile strength is increased. The New York Building Department accepts wood prepared by the Bachert process, but not by the other two processes. It is said that timbers as large as 12 inches $\times$ 12 inches can be successfully treated, but the cost increases very much with the size. The effect of the treatment appears to be permanent. Corrosion has given trouble—probably due to imperfect treatment of the wood. It is rather more difficult to work than ordinary wood, and takes a very good finish. The cost of the treated wood renders it almost prohibitive for general use.

(2) Fire-retardant coatings. There are many such in the market, and some appear to be fairly efficacious; but in the absence of any specific or convincing tests, it is not attempted to judge of their respective merits. The Committee recommend the Association to institute proper tests to determine the value of these different compounds and suggest general conditions to be observed *in making* such tests.

C. H. M.

A Case of Poisoning by Carbonic-Oxide Gas. Otto Peschke.

(Gesundheits-Ingenieur, 15 March, 1901, p. 72.)

Attention is directed to the recent deaths of a married couple, the husband aged 39 years and the wife aged 36 years, in a house situated in the western quarter of Berlin. It would seem that the wife had prepared a hot bath in a room in which was an apparatus for heating the water by means of gas-jets. The husband, who had been out, ascertained, on his return, that his wife was in the bath-room, and found her in a state of unconsciousness. He thereupon hastened to obtain some wine from a neighbouring room, but on getting back to the bathroom and in stooping down to give her some wine in a glass he also was overcome by the gas, and fell down beside her, and the two dead bodies were after a very short time discovered by a neighbour residing on the floor above, who had been alarmed by a strong and peculiar smell of gas. The deaths, on the evidence of two medical men who had been called in, were certified as being due to poisoning by carbonic oxide in consequence of the inhalation of coal gas; but the Author, who was subsequently employed as an expert by an insurance office in which the husband's life was insured, gives various reasons for his belief that death was caused by inhaling the products of combustion which he was able to prove contained a large percentage of carbonic-oxide gas. The results of certain trials of the stove, the construction of the apparatus and of the defective flue for the exit of waste products are explained.

G. R. R.

Javal's Acetylene Gazogene. G. Guéroult.

(La Nature, 4 May, 1901, p. 357.)

The objects aimed at in this apparatus are to produce acetylene gas in limited quantities and of the best quality without any delicate or complicated mechanism, to render any increase of pressure or temperature impossible, to guard against any return of the gas by back-pressure, to obviate any accidental introduction of atmospheric air, and to reduce the charging to one single operation of the very simplest character. By reference to an illustration, the Author describes the apparatus which consists in the main of a small gas-holder which rises or falls as it fills and empties with gas, having a generator placed on one side of it. The descent of the crown of the holder sets in motion a ring of small metal vessels, fixed above it, each carrying one charge of calcium carbide, which in turn open when the cover of the gas-holder falls to a given level and discharge their contents into water. By this means a small volume of acetylene gas is from

time to time generated. The action of the apparatus is automatic as the crown of the gas-holder operates by its weight, by means of a chain attachment, and effects the advance as required of a fresh vessel filled with the carbide. The vessels are moved forward by a stop acted on by a lever. The fall of the carbide opens a water-tap which delivers a stream of water, and this carries down with it the carbide into the generator; the extra flush of water washes away any impurities.

G. R. R.

Dissolved Acetylene. MAURICE FOUCHÉ.

(La Nature, 6 April, 1901, p. 289.)

The dangers attending the use of acetylene gas for illuminating purposes, where this gas is generated direct by the introduction of calcium carbide into water, are recalled. These dangers are mainly owing to the accidental admixture of this gas with the atmosphere, thus forming a highly explosive compound, or they may be due to its endothermic properties, in consequence of which it is liable under certain conditions to become decomposed with the evolution of heat and consequent great increase of pressure due to expansion. In order to obviate these risks, it has been proposed by two French engineers, Messrs. Claude and Hess, to dissolve this gas in acetone. The liquor in question, which boils at 56° C., is not expensive and it will not freeze. The quantity of the gas which it can take up is about equivalent to the pressure, and amounts to about twenty-four volumes per atmosphere at a temperature of 15° C., so that, at the moderate pressure of ten atmospheres, 1 litre of acetone will dissolve 240 litres of acetylene, with a slight increase in volume. This solution has the remarkable property of being no longer explosive. Some account is given of the researches of Messrs. Berthelot and Vieille, and a description follows of the mode of using the dissolved gas for illuminating purposes. The pressure has to be reduced from ten atmospheres to that of a column of 2 inches or 3 inches of water, by means of a special reducing valve attached to the iron cylinders in which the solution is distributed for consumption. The gas is forced through a dry meter with a manometer attached, and is consumed in a special burner. The various types of cylinders are described, as for instance, one containing 1,200 litres of the gas employed on the Belleville funicular railway; also large drums holding 55 gallons of acetone and storing 883 cubic feet of gas, and a special van holding four of these large sized drums, where an exceptionally large volume of acetylene gas is needed.

Illustrations are given of the apparatus, together with details of the above plant.

G. R. R.

Automatic Electric Block-Signals for Railways. L. KOHLFÜRST.

(Elektrotechn. Zeitschr., vol. xxi., 1900, pp. 929–932, 950–952, 980–982, 998–1001, and 1017–1019.)

In these articles, the most important systems of automatic electric block-signalling are fully described. The first given is that of Joseph Sacek, which is designed to work with steam locomotives. On the locomotive is mounted a small dynamo or an accumulator, one terminal of which is earthed, and the other is connected directly to a brush on one side of the locomotive, and also through the coils of a Hughes electromagnet to a brush on the other side of the locomotive, this electromagnet being adapted to actuate either a steam whistle or a brake-releasing device. The passage of the train over the rails completes local battery circuits, including relays, which block the line for two sections of line in the rear, so that a following train fitted with the apparatus above-mentioned will be warned that the line is not clear. A system of mercury contacts acting by the compression of air in a closed vessel under the rails on the passage of a train is also described for use in connection with this system.

The systems of Timmis-Lavezzari, Krizik, and Ceradini are described. The latter system comprises blocking signals on both the line and locomotive. The signals on the locomotive consist of two Lartigue steam whistles, one of which is sounded by an electromagnetically operated valve when the train enters a block-section, and the other is similarly sounded if the section is clear, this being effected by a battery on the train and fixed contacts on the track. The line is divided up into sections, in each of which is an instrument comprising two electromagnets. These electromagnets oscillate a balance-beam, whereby a signal disk is rotated and contacts are made or broken, controlling the sounding of the "line clear" whistle on the locomotive.

The Siemens and Halske partly automatic system comprises an electromagnetically controlled pawl, whereby the signal is held in the "line clear" position against the action of gravity, this pawl being tripped by the action of a current in a circuit completed by the passage of a train over the section, so as to allow the signal to move into the "danger" position. The signal is returned to the "line clear" position by hand.

Basanta's system, in addition to giving audible signals, permits telephonic communication between the carriages and between the train and the stations.

The "danger" signals are given exclusively on the locomotive, on which is arranged an alternate-current dynamo, giving from 10 volts to 40 volts. From station to station insulated conductors, l, are arranged parallel to the rails; these conductors do not, however, meet, but are overlapped by separated insulated conductors, l_2, at the stations, whilst two short sections of insulated conductor, l_1, are arranged respectively about 500 metres in front

of and behind each of the points, *e.g.*, of the station-loop of a single-line railway. The locomotive bears three brushes, each adapted to engage respectively with one of these series of conductors, the locomotive itself and the rails serving as a common return. The locomotive is also provided with a telephone set, a magneto-machine, and two alarms, each giving notes of distinct character and earthed through the dynamo; the stations are fitted with one alarm, switches, a telephone set, and two rheostats; and the sections l_1 to an alarm operated by clockwork and provided with an electromagnetic release. One of the alarms on the locomotive serves as the "danger" signal, and is operated by depressing keys either at the stations or in the signal-boxes, these keys putting the conductors l_2 to earth. By earthing l, the other alarm on the locomotive is rung, after which telephonic communication can be opened with the train, whilst the clockwork alarm is released when the locomotive passes each section l, and rings for five minutes. The train can always ring up the stations by means of the magneto, whereupon the telephone can be switched into circuit.

C. K. F.

Electric Automobiles. E. A. Sperry.

(Electrical Review, New York, vol. xxxvi., 1900, p. 596, and pp. 608–610. Paper read before the National Electric Light Association, 24 May, 1900.)

Recent tests showed that for two batteries of the same capacity on the same carriage, and having a life of 3,000 ton-miles to 4,000 ton-miles, a Planté battery ran 20 miles per charge, weighed 1,260 lbs., gave 5·25 watt-hours per lb., and required 21 lbs. of cell per ton-mile; a Faure battery ran 29 miles per charge, weighed 980 lbs., gave 6·5 watt-hours per lb., and required 30 lbs. of cell per ton-mile. The remarkable advantage of halving the weight of batteries for the same cost and output is pointed out.

M. O'G.

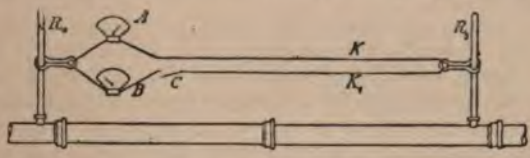
Measurement of Tramway Currents in Water-pipes. S. Krohn.

(Elektrotechn. Zeitschr., vol. xxii., 28 March, 1901, pp. 269-271.)

The Author was instructed by the Union Electricity Company to examine into the state of affairs in a certain town where it was known that corrosion was taking place, and, if possible, to suggest a remedy. His method of examination was as follows:—There was a small truck on which was mounted a cable drum, the latter carrying two cables about 300 yards long, having sectional areas respectively of 4 and 14 square millimetres. The method of measurement may be explained by the aid of the accompanying

diagram. R_1 and R_2 are two gas- or water-pipes, leading to houses about 250 yards apart; these pipes are connected, as shown, to the main, the currents in which have to be measured. The above-mentioned cables K and K_1 are connected through a voltmeter and ammeter respectively to the pipes R_1 and R_2. When the switch C is open, let the voltmeter reading be V; when the switch is closed, let voltmeter reading be V_1, and ammeter reading be i; then the current flowing in the main gas-pipe is $= i \frac{V}{V-V_1}$, and the resistance of the length of piping is $= \frac{V-V_1}{i}$.

The Author describes more particularly the connections which existed between the gas-pipes, rails, and switchboard on the system which he examined, and, as the result of alterations made, the current flowing in the gas-pipes was reduced from 30 amperes to 44 milliamperes. Obviously, owing to the varying currents, V, V_1, and i can only be read as the mean of a large number of readings, taken at stated intervals, say, of 5 seconds. Diagrams are given showing the way in which the readings varied. Thus, though the mean value of the current in the gas-pipes was reduced



to 44 milliamperes, it rose momentarily as high as 88, and fell as low as 12.

Finally, the Author considers the conditions which may reasonably be imposed on a tramway company with a view to the prevention of electrolysis. He objects entirely to the English system of imposing a definite fall of voltage in the rails. He points out that the earth currents depend not only on the fall in volts, but also on the nature and condition of the soil. If a definite fall of volts produces a condition of safety in ground that is habitually wet or marshy, it is unnecessarily high for ground that is sandy or rocky, and therefore may impose very unnecessary expense on the tramway company. The want of elasticity in such a condition is considered a defect, inasmuch as it cannot reasonably be applied to all kinds of tramways, both urban and rural. He suggests as an alternative that when the line is in working order, the currents in gas- and water-pipes should be measured, and at no time should a pipe of 3 centimetres diameter carry more than 1 ampere, and so on in proportion. If this or some similar limit were exceeded, the tramway company should be called on to rectify the defect.

W. H. S.

Thermodynamical Properties of Superheated Steam and the Dryness of Saturated Steam. J. H. GRINDLEY.

(Manchester Literary and Philosophic l Society, Memoir 45, vol. iii. 1900–1901, pp. 1–11.)

For superheated steam, (1) the Author draws up from his former experimental results a Table of the total heat of its formation at different pressures and temperatures from water at 32° F.; (2) by utilising Ramsay and Young's experiments he calculates the values of the isopiestic specific heat for temperatures between 290·3° and 426·5° F.; these, compared with the values formerly found by employing Regnault's linear relation between the total heat of saturated steam and the temperature, throw doubt on this relation; (3) he finds that for adiabatic change between 1 and 5 atmospheres and 210° and 330° F. the values of pv^n are constant when $n = 1{\cdot}286$; (4) he shows that the product of the isopiestic specific heat and the cooling effect on expansion is $\frac{D}{a^p}$ for pressure p, where $D = 1{\cdot}625$ and $a = 1{\cdot}000023$, when p is measured in lbs. per square foot.

For dry saturated steam the specific volumes deduced from Ramsay and Young's experiments, and those lately given by Callendar, agree in differing from those obtained from Regnault's values for the latent heat by amounts varying from 1·33 per cent. under 1 atmosphere to 3·4 per cent. under 21 atmospheres in excess, thus apparently showing that Regnault's values for the latent heat are too small by these percentages.

R. E. B.

Koerting 350-*HP. Gas-Engine.*

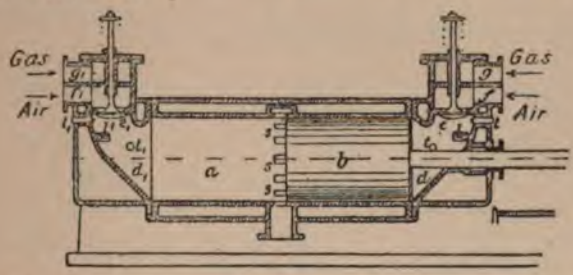
(Engineer, vol. xci., 4 January, 1901, pp. 23, 24.)

This two-cycle engine has one motor cylinder double-acting, like a steam-engine, with a piston rod and cross-head working through guides, and a crank. There is an admission lift valve, shown in the figure, at each end of the cylinder, driven from a cam shaft. The discharge of the burnt products is through ports, *s*, and through the annular passage around the middle of the cylinder uncovered by the piston. The length of the double-acting piston is equal to the stroke, less the width of the exhaust ports. The gas and air enter the admission valves by separate pipes from two double-acting pumps, both driven from an auxiliary crank 110° in advance of the motor crank. There is a projection in the cylinder below each admission valve, to prevent the heavy incoming gases streaming down to the exhaust ports, leaving the *burnt* products in the upper part of the cylinder. A scavenger charge of air is first admitted between the products of combustion

and the fresh explosive charge. To ensure prompt ignition there are two electric ignition ports at both ends of the cylinder at two different places in the compression space.

The usual cycle is carried out in two strokes instead of four. At light loads the gas-pump piston-valves, acted on by the governor, hold open the connection with the gas-pipe longer, and thus as the speed increases more gas is returned to the pipe and less passes to the cylinder.

The stuffing-box has metallic packing, and is carefully water-cooled. The cooling water for the piston and piston-rod is conveyed through tubes of the sliding telescopic type, moving to fro with the cross-head.



The first 350-HP. engine of this kind was tested by Meyer, at the works of Messrs. Koerting. The diameter of the motor cylinder was 21·6 inches, stroke 37·7 inches; diameter of the air-pump 24·4 inches, of the gas-pump 19·6 inches, and stroke of both pumps 27·5 inches.

The engine was driven by power-gas from a Koerting producer, and the work was absorbed by an electric brake which was not very reliable. The consumption was taken in a large gas-meter, and the (lower) heating value of the gas frequently measured by means of a Junkers calorimeter. The results in a trial run of an hour at full load were:

Mean (metric) power indicated in the motor cylinder	544 HP.
" " " " " pumps	63 "
" " " effective indicated	481 "
" " " on the brake	341·5 "
Mechanical efficiency	71 per cent.
Mean number of revolutions per minute	101
Heating value of the gas (lower) B.T.U. per cubic foot	129

Consumption of Gas per Hour.

Consumption of gas per total I.HP. (including pumps)	51 cubic feet.
" " " " (excluding pumps)	58 "
" " " brake HP.	81·5 "

Thermal Efficiency of Engine.

Thermal efficiency per gross I.HP.	37·9 per cent.
" " " effective I.HP.	33·5 "
" " " brake HP.	23·8 "

The compression pressure was 12·5 atmospheres (absolute), and the maximum explosion pressure 27·5 atmospheres. The gas consumption could not be quite satisfactorily verified. Assuming it was 4 per cent. or 5 per cent. above the figures given, the heat utilisation was still very good, viz., 24 per cent. of the heat supplied to the engine converted into useful work on the brake. It remains to be seen how the double-acting piston and stuffing-box wear.

W. R.

Power Gas and Large Gas-Engines.[1] H. A. Humphrey.

(Institution of Mechanical Engineers, vol. i., January, 1901. Proceedings, pp. 41–118. Discussion, pp. 119–247.)

In an appendix the Author gives the cost of 1 B.HP.-hour in manufacturing works, as the mean of a large number of actual results; it varies from 0·68*d.* for ordinary works with fairly uniform load to 1·80*d.* for small works with varying load.

A description is given of the Mond gas-producer, illustrated by five diagrams and four photographs. Common bituminous slack is used as fuel, and is fed into the producer bell. On reaching the hot zone of fuel the tar is converted into a fixed gas, and the slack then descends into the body of the producer, where it is acted on by an air-blast, which has been saturated with steam at 85° C. and superheated. The steam used per ton of fuel gasified is 2½ tons; this large quantity keeps the temperature of the producer within such limits as to prevent the formation of clinkers or the destruction of the ammonia. Half a ton of steam is decomposed per ton of fuel burnt, yielding 29 per cent. by volume of hydrogen in the final gas. The hot gas and undecomposed steam, leaving the producer, pass first through a tubular regenerator in the opposite direction to the incoming blast. An exchange of heat takes place, and the blast is still further heated by passing down the annular space between the two shells of the producer. The hot gases then pass through a washer, in which they meet a water-spray thrown up by revolving dashers, and are thereby cooled to about 90° C. The gas then passes upwards through a lead-lined tower filled with tiles, where it meets a downward flow of acid liquor circulated by pumps, consisting of sulphate of ammonia with about 4 per cent. free sulphuric acid. The ammonia of the gas combines with the free acid, yielding sulphate of ammonia, and, to make the process continuous, some sulphate liquor is constantly withdrawn or evaporated, while free acid is added. The gas, now freed from ammonia, passes up a cooling tower, where it meets a downward stream of cold water. The heated water is utilised in an air-

[1] The substance of this Paper was given in vol. cxlv., p. 420 (pamphlet *Abstracts*, p. 69). Additional particulars are here presented, along with an *abstract* of the discussion.

heating tower to heat the air-blast from the blowers. In Appendix I. are given figures relating to the Mond plant and gas. The composition of the gas is, in volumes per cent., 11 of CO, 29 of H, 2 of CH_4, 16 of CO_2, and 42 of N. The calorific value of the fuel used was 6,900,000 large calories per ton of dry fuel. A ton of moist fuel yields 4·02 cubic metres of gas, of a calorific value of 1,414 large calories per cubic metre. The efficiency of production is 84 per cent. One volume of Mond gas requires 1·15 volumes of air for complete combustion, and gives a theoretical temperature of 1,610° C. The ammonia recovered is about 1 per cent. by weight of the fuel gasified, and has a value of about 8*s.* per ton of fuel, which at the pit costs 2*s.* 6*d.* per ton, and delivered at Winnington 6*s.* 9*d.* per ton.

Coming to gas-engines, in Appendix III. are given particulars of some large engines; a Crossley engine of 450 I.HP. and a Premier engine of 650 I.HP. are running day and night on Mond gas at Brunner, Mond & Co.'s works; a 700-I.HP. Simplex engine is running on blast-furnace gas at Seraing, and two 1,500 I.HP. Westinghouse engines are being built for use with natural gas. In Appendixes IV. and XIV. are given full particulars of the above-mentioned Crossley and Premier gas-engines, and of some large Œchelhäuser and Otto engines; these are illustrated by numerous diagrams and photographs. In Appendix V. are given the results of tests on the Crossley and Premier engines, running with Mond gas. The Crossley engine has two cylinders, 26 inches by 36 inches stroke. Working at 314 B.HP. at 152 revolutions per minute, the mechanical efficiency was 90·76 per cent., and the thermal efficiency (I.HP.) 27·2 per cent.; the consumption of Mond gas was 60 cubic feet per I.HP.-hour, or 72 cubic feet per B.HP.-hour. Diagrams of the valve motion are given, and indicator diagrams, showing a maximum pressure of about 240 lbs. per square inch, with an effective pressure of 63 lbs. per square inch, and a clearance of about 26 per cent. of the working stroke; there are also given diagrams taken with a light spring, of firing cycles, and cycles taking air only, and curves are given showing at different speeds the HP. lost in running idle, the HP. lost in fluid resistance when exploding, and the percentage of return stroke when the compression curve crosses the atmospheric line.

The Premier engine is a two-cylinder tandem engine with positive scavenging and water-cooled pistons; the cylinders are 28½ inches by 30 inches stroke. The engine worked at 368 B.HP. at 128 revolutions per minute. The mechanical efficiency was 81 per cent., and the thermal efficiency (I.HP.) 30·4 per cent.; the consumption of Mond gas was 52 cubic feet per I.HP.-hour, or 69 cubic feet per B.HP.-hour. One I.HP.-hour was obtained from 0·88 lb. of moist bituminous slack, containing only 62 per cent. of carbon. Indicator diagrams are given showing a maximum pressure of 325 lbs. per square inch, and an effective pressure of 108 lbs. per square inch; the amount of the clearance is 27 per cent. of the working stroke.

Appendix VI. gives the results of an official trial of a 60-N.HP.

Crossley engine coupled to a Siemens dynamo, and supplied with Mond gas. Appendix VII. is a report on the working of this engine; during 1898 and 1899 it ran during 96·6 per cent. of the whole time, at an average I.HP. of 115, and has run for 3,300 hours without a stop. The average consumption during the 2 years was 67·7 cubic feet of Mond gas, or 1·055 lbs. of slack, per I.HP.-hour, and 117·3 cubic feet or 1·82 lbs. of slack per E.HP.-hour. Appendix VIII. contains figures relating to the test of a 65-B.HP. Westinghouse engine with natural gas, and gives indicator diagrams.

Appendix XIII. gives a large number of tests with very full particulars of various Continental engines, namely, a test by Witz on a 200-HP. Simplex engine at Seraing, and one by Hubert on a 600-HP. engine at the same place, the engines using blast furnace gas. The heat balance-sheet given by Hubert for the 600-HP. engine is:—

	Per Cent.
Heat converted into work in the cylinder	28
Heat carried away by water	52
„ „ „ gases and losses	20

Eight pages of this Appendix are occupied by brake trials conducted by Delamare, Debouttéville, and Cockerill on a 600-HP. engine working with blast-furnace gas.

Appendix X. gives comparative figures of the cost of fuel per kilowatt-hour with steam and gas. Unwin's ideal estimate for continuous running made the cost 0·194*d.* per unit; Kennedy's ideal estimate for a central station gave 0·210*d.*; the average cost for eighty-three electric light stations is 0·778*d.*; the actual cost with Mond gas at Winnington is 0·048*d.* Appendix IX. contains an estimate of capital and running costs for a 20,000-HP. central station gas plant, worked with Mond gas at various load factors.

The Author made experiments on the speed variation during the strokes of the Crossley and Premier engines, by means of an electric tuning-fork tracing vibrations on a smoked drum. Diagrams are given for both engines, showing throughout the stroke, the inertia forces due to the reciprocating parts, the indicator diagram corrected for inertia, the turning moment on the crank-shaft, and the speed. In the Crossley engine, with both cylinders firing every time, the variation from the mean speed at full load was 0·094 of 1 per cent., and on the "hit-and-miss" system at three-quarter load it was 0·976 per cent. Curves are given showing the variation of efficiency due to variation in the gas mixture; the curves are sufficiently flat to show that governing is possible by controlling the admission of gas, instead of by the usual hit-and-miss system. Appendix XII. contains a full Table of gases saturated with water vapour at different temperatures, and Appendix XI. details the precautions taken to ensure accuracy in the Author's experiments.

Discussion.—W. J. Crossley referred to the tests of his gas-engine, and explained the reasons which led him to adopt low compression. He gave indicator diagram and figures relating to a

test of a 150-I.HP. engine, which with coal gas showed a thermal efficiency of 31·8 per cent. He had given much attention to the fluid resistance of engines when missing a stroke, and had devised methods for cutting off the gas at any desired portion of the stroke, so that the piston made a slight vacuum which assisted its return. He believed that the irregular sequence of explosions in his tandem engines was the best, as it made possible a far better design of engine. He had a small Mond gas plant at his works, which ran successfully, except that the sawdust in the scrubbers required very frequent changing. J. E. Dowson spoke on the necessity of gas-holders; he thought it would not be safe to work large engines without a gas-holder to check the great fluctuations of pressure caused by the suction of the piston. He supposed the reason that no gas-holder was used at Winnington was that only a very small proportion of the gas generated was used in the engines, and that the large gas-mains acted as a gas-holder. He considered the proportion of 16 per cent. of CO_2 contained in the gas called for some improvement, and expected that if worked without sulphate recovery, the plant would not give very economical results. A. Rollason gave particulars of a Mond plant of 1,000 I.HP. erected at the Premier gas-engine works, without sulphate recovery. At full load, 1 lb. of Nottingham slack gave 72·25 cubic feet of gas, of a calorific value of 145·9 B.Th.U. per cubic foot, while at one-third load it gave 70·85 cubic feet, of 144·5 B.Th.U. The calorific value of the slack was 12,200 B.Th.U. per lb., and the thermal efficiency of the producer was 86·4 per cent. The stand-by losses for 14 hours out of the 24 hours were, at full load 3 per cent., and at one-third load 5·7 per cent. of the total fuel consumed. F. W. Burstall, in speaking of governing by throttling, said that the troubles found were due to failure in ignition; the only way to properly ignite a weak mixture was by the electric spark, with a variable lead, depending on the mixture. He agreed with Slaby in believing that combustion was complete at the point of maximum temperature, but said that when the charge was extremely weak and the burning slow, there occurred sometimes after-burning, which gave an expansion line just above the adiabatic. According to theory this should give inferior efficiency, because the heat was not added at the maximum temperature, and he had made experiments which bore out this conclusion. W. Dixon said there were gas-producers with recovery plants in Great Britain of larger size and giving better results than the Mond producer. He criticised the Author's figures, comparing costs of power on the Mond system and in central electric stations. D. Clerk said that the high temperature proper to the production of good gas was antagonistic to the production of ammonia; Mond kept down the temperature by the use of steam in great quantity, and had consequently to make arrangements to recover the heat. He did not consider the producer efficient; the figure of 84·1 per cent. given as the thermal efficiency was misleading, as no account was taken of the heat introduced in the form of steam; allowing for this the efficiency came down to 67 per cent. Further, the

quantity of gas generated had not been measured, but only deduced from the weights of carbon in the fuel and that lost in tar and in deposits in the flues. He did not think the efficiency could be over 50 per cent. Referring to Crossley's engine, as the piston was not water-cooled, he thought the makers were right in keeping the compression down to 60 lbs. per square inch. The expansion of the piston was so considerable in large engines that a large clearance had to be left to avoid seizure. B. Donkin gave tables showing the results of twelve gas-engine tests with power gas of 150 B.T.U. per cubic foot, and of six tests of gas-engines in America using natural gas, with a calorific value of about 1,000 B.T.U. per cubic foot. As regards the calorific values of the gases given by the Author, he thought the lesser value should be taken, as this was the custom in all countries except France. He compared the thermal efficiency (B.HP.) of various engines. It varied from about 12 per cent. with steam to about 30 per cent. with oil engines, which were more efficient than gas-engines. W. Robinson had tested the Mond gas plant and a 500-HP. Premier engine at Sandiacre, and found a thermal efficiency of over 30 per cent. He noted the remarkable uniformity in the quality of the Mond gas. He was convinced of the accuracy of the Author's estimate of the quantity of gas, as calculated from the carbon. The efficiency found at Sandiacre for the Mond producer was 70 per cent. In the Dowson gas-producer the composition of the gas was very variable; in a two-days' test, with regular charging and constant steam pressure, it varied between 137 and 170 B.T.U. per cubic foot. W. J. Crossley compared the figures given for his engine and the Premier engine, showing that the friction loss in the latter was 18·78 per cent., while in his it was 9·33 per cent.; he thought that positive scavenging, which accounted for this difference, was too expensive. E. B. Ellington criticised the Author's comparative figures for the cost per unit in actual and ideal steam stations and in a Mond gas station. He considered that the total cost for fuel with Mond gas would be 0·15*d.* instead of 0·048*d.* In the London Hydraulic Power Company's Wapping station, for the whole year the cost per unit of fuel was 0·215*d.*, and of all station charges 0·465*d.*; the load factor was only 39 per cent. From a comparison of the costs and the thermal efficiencies of steam and gas-engines, he concluded that the efficiency of a steam boiler was about the same as that of a gas-producer. He thought that the saving in fuel obtained by the Mond gas plant was of little importance for central stations, as the rates and charges on capital cost were far more important factors. J. H. Hamilton compared the Premier and Crossley engines, to the advantage of the former; he gave full particulars of the Premier engine, pointing out, among other things, that the compression every back-stroke was so arranged that there was never a pull on the connecting rod, thus avoiding all knocking at the joints. W. G. Goodchild gave particulars of the gas plant erected by the Midland Railway Company at Leicester. In the last half-year the fuel consumed was 3·1 lbs. per unit, costing 0·34d.

The Author, in reply, said that the cost of sawdust, shavings, and labour in cleaning and refilling the scrubbers amounted to 4*d.* a day for a 1,000-HP. plant running continuously. The time taken to start the Crossley 400-HP. gas-engine from rest and to parallel it with the others was 2½ minutes. The engine had run for 57 days with only two stops required by the electrical plant. The balance-sheets of heat quantities for the Crossley and Premier engines were—

	Crossley.	Premier.
Heat converted into work	27·8	33·65
Heat lost in cooling water	24·2	27·56
„ „ exhaust and radiation . . .	48·0	38·79

There was no tar at all deposited from the gas issuing from the Mond producer; a very small quantity appeared in the sulphate of ammonia, and that collected from the washers, towers, and mains was too small to have any value. He gave full details of the trial of the Premier engine at Sandiacre works, mentioned by Rollason. He did not agree with Clerk's criticisms; when the Mond plant worked without sulphate recovery, the fuel for steam-raising was less than with the Dowson plant; when worked with sulphate recovery, more steam was needed, but against this should be placed the value of the by-products. His estimate of the quantity of gas produced at Winnington had been borne out by the measurements at Sandiacre; Clerk was therefore in error in estimating the efficiency at 50 per cent. At Oberhausen, gas dynamos were regularly paralleled for polyphase working, and gave no trouble.

Communications.—J. E. Dowson criticised the figures given in Donkin's Table of tests as being in many cases inaccurate. He gave a table of twenty-six tests on different engines working with his gas plant. In reply to Robinson's statement that the quality of Dowson gas was variable, he said that in a 110-B.HP. plant, in five hours the maximum variation in the calorific value of the gas was 5 per cent. G. C. Jones dealt with the efficiency of the Mond plant in detail, and concluded that it was 70 per cent., instead of 84·1 per cent., as given by the Author. M. Münzel, of the Gas Motoren Fabrik, Deutz, wrote that it was quite practicable to parallel polyphase machines, if the engine were governed by varying the gas admission, not by missing explosions. Electric ignition must be used. He gave indicator diagrams of a 1,200-B.HP. Deutz engine using blast-furnace gas. J. D. Roots suggested a method of compounding gas-engines, and illustrated it by diagrams. R. Threlfall referred to the curve of HP. lost in fluid resistance; assuming that the resistance in viscous flow is proportional to the speed, he could account for the quicker increase of resistance shown in the curve only by supposing that the viscosity of the gases increased; this would require their temperature to be raised from 20° to 140° C. in the inspiration. He thought it most important to ensure a thorough mixture of the gases by breaking them up into thin streams, as was done in the Premier engine. B. H. Thwaite showed by a diagram the effect on the calorific value of producer-

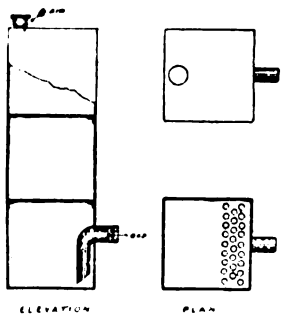
gas, of additions of CO, C_2H_4, CH_4, and H; the effect produced by the latter three is so much greater than that produced by CO that a producer-gas containing them in any quantity must be very variable in calorific value. Measured by volume the heat value of H is no greater than that of CO, and he considered that the ideal power-gas would contain 30 volumes per cent. of CO and 3 of H. The Author, in reply to the written communications, dealt with the various possible ways of considering the efficiency of a gas-producer.

G. H. B.

New Gas-Producer. J. A. Purves.

(Inst. Engin. and Shipbuilders, Trans., vol. xliv., November, pp. 18–23. Discussion, December, 1900, pp. 4–18.)

"Air-gas" consists of a mixture of air and vapour of petroleum or liquid hydrocarbon, such as gasolene, pretroleum spirit, or pentane. The proportion of vapour which can be taken up varies with the temperature of air and the volatility of the petroleum. Air-carburetters may be divided into three classes:—(1) Air is forced under pressure through or over liquid petroleum; (2) on account of the danger of using large quantities of liquid petroleum, an absorbent is employed to take up the hydrocarbon, and air is forced over or through the absorbent; (3) air flows by gravity through the "aero-gas fountain" described in this Paper.



In 1895, Naum Notkin, of Moscow, took advantage of the property that carburetted air is heavier than ordinary air. His automatic carburetter, called an "aero-gas fountain," consists of a tin vessel, shown in the figure, with an orifice at the top and a bent "draw-off" pipe at the bottom filled with a porous material (wood pulp) which is impregnated with one of the lighter hydro-carbons. Two perforated shelves give a long travel to and distributes the air. Air enters at the top, and taking up hydro-carbon vapour becomes heavier and gravitates through the mass of absorbent, taking up more and more of the vapour, until it issues from the lower orifice, and may be used for lighting, heating, and power purposes. The gaseous mixture becomes heavier and cooler by the rapid volatilisation of petroleum.

Argand burners with steatite centres and very wide gasways give with this "air-gas" a light of high illuminating power. No attention is necessary beyond the refilling of the carburetter when it becomes empty. Illustrations are given in the Paper showing

the application of this carburetter to table and street lamps, ship's lights; also to stoves and heaters. When the carburetter is exhausted of petrol, the tin box can be lifted out and a fresh one put in its place.

The yield of the aero-gas from a gallon of petroleum will give in an ordinary Argand burner from 700 candle-power-hours to 1,000 candle-power-hours, depending upon the quality of the petroleum used. With petroleum at 1*s.* per gallon the cost of light is equivalent to that of 14 candle-power gas at 3*s.* 4*d.* per 1,000 cubic feet, giving 2·8 candle-power-hours per cubic foot. The gas can be used more economically in the Wenham and Siemens regenerative burners than in the Argand, and still greater efficiency is obtained with incandescent mantles. The aero-gas fountain can be used for gas-engines, motor cars, and for launches.

Discussion.—T. B. Murray pointed out the only novel feature was that the apparatus worked by gravity, and hence did not require a fan to blow or force air through the gasoline. This property was of little or no value for motor cars or gas-engines, since the suction caused by the forward stroke of the piston gave ample flow of air for carburation. Somewhat similar carburetters had been tried and abandoned for several reasons, such as the difficulty of obtaining a proper explosive mixture due to the varying temperature and humidity of the atmosphere; consequently in a car the mixing valves required continual adjusting by an expert to get good results. Again, the lighter hydrocarbons were evaporated first, leaving behind a residue, in some cases heavy and difficult of volatilisation with cold, damp air. A spray carburetter was more suitable, since it depended on mechanical action, and in practice a good explosive mixture could be obtained under all conditions—winter and summer, wet or dry. He asked how the petrol was fed into the carburetter, and what was the total weight of the latter containing the four gallons of petrol required for a 100-miles run. F. J. Rowan said the convenience of the Notkin apparatus was due to the absence of all machinery. There were no waste products as in the case of acetylene and similar gas generators. Gasoline vapour was from three times to four times the weight of air, so that any slight variation of barometric pressure could not affect the action very much. He thought that the air, instead of mixing with the vapour, acted more like a piston to force the gasoline vapour down the pipes, or rather, to occupy the space left void in the gas fountain by the vapour falling. In the case of large buildings in France, a battery of gas fountains was placed near the roof, and the only precaution needed to insure constant supply was to put smaller pipes in the lower part of the building, because the pressure increased with the "head" of vapour, similarly to water. N. D. Macdonald had tested the apparatus on an autocar in which it was desirable to get rid of the difficulties and dangers of carrying liquid petrol. A regulator enabled the density of the gas to be delicately adjusted. J. Macdonald had driven from London to York, a distance of 200 miles, without any delay or accident, his

motor car being fitted with a Notkin generator, which behaved beautifully in spite of a storm of hail, rain, and wind all the way. A. Wilson remarked that the oil used by Purves had a specific gravity of 0·65, cost 1*s.* per gallon, and gave 700 candle-power-hours to 1,000 candle-power-hours; whereas the oil he (Wilson) used at Dawsholm gas works for enriching purposes had a specific gravity of 0·85, cost about half the price, and yielded over 1,500 candle-power-hours per gallon. The difference was due to the fact that the admixture of 1 per cent. of air with petroleum gas reduced the candle-power about 6 per cent. The atmospheric pressure would be the same on the top of the system as at the burners, and would not, he thought, affect the question at all. R. Watson considered the apparatus was open to a rather serious objection, viz., danger of fire or explosion, besides a disagreeable smell. The air was admitted through a regulator, and unless this was constructed to prevent the exit of carburetted air by diffusion, when the light was shut off and the downward current stopped, there would be at least the smell of the spirit used in carburetting the air. Q. Galbraith was of opinion that the pressure required to drive the gas through the pipes would be apt to vary with the state of the atmosphere. All the driving force available would be the difference in weight between the vaporised gas and the outside air—the one varied with the quality of the gasoline used, and the other with the weather. When both were against the gas there would be a bad light, or none at all. He had had this trouble in twenty-five years' experience of machines in which air under pressure was forced through gasoline by means of weights and fans—positive mechanical appliances. Purves, in reply, said that in large installations at Lyons for the illumination of a hospital, barracks, church and college, the gas fountains were stored in the upper part of the buildings in series battery form with a system of graduated piping, and worked satisfactorily. The weight of the vapour from petroleum, of specific gravity 0·68, being three times to four times the weight of air, was amply sufficient to produce a flow and overcome the friction in the pipes with curved bends—sharp ones being avoided. With the most suitable petroleum, of 0·65 specific gravity to 0·66 specific gravity, the weight of the vapour was $2\frac{3}{4}$ times the weight of air. As to motor cars, the difficulties raised by Murray had been got over by a special carburetter and regulator. On the 6 HP. Diamler motor it was usual to take one gallon of petrol for a run of 20 miles. On the run from London to York the petrol used amounted roughly to half a gallon per 20 miles. The residue was small, and the clogging up of the absorbent very trifling. The absorbent cost 5*s.* per cwt. to 6*s.* per cwt., so that the cost of filling the box was a fraction of a penny. A gallon of the most suitable petroleum should weigh 6·5 lbs. A blue and inefficient light only could be obtained from paraffin; and one of the lighter and more volatile hydrocarbons must be used. He had *tried, but* failed, to induce a back draught so as to produce an *explosion* in the apparatus or set it on fire. The carburetters on

motor cars were 2 feet in length by 1 foot square, and each held three gallons of petroleum. When one was exhausted, as indicated, by the reduction in the power of the engine, another could be used.

W. R.

Engines for the Brooklyn Edison Plant.

(American Electrician, vol. xiii., March, 1901, pp. 108–110.)

Each engine is vertical cross-compound with Corliss gear, having cylinders 46 inches and 86 inches by 60 inches stroke. Its most economical speed is 75 revolutions per minute, developing 3,750 HP., but it will run up to 7,500 HP. with safety. The high-pressure cylinder clearance is 3 per cent. and the low-pressure 2 per cent. Steam jackets are not used, as the Westinghouse Company find that after a piston speed of 600 feet per minute they are of little or no use. A reheater, however, is employed in the receiver having a surface of 1,500 square feet. Higher values of reheating surface have been advocated by some builders, but this proportion gives very good results and has certain distinct advantages. The steam passing through the engine is passed through the inside of the heater tubes, and boiler steam is used on the outside. The connecting-rods are 5½ crank-lengths. The shaft is hollow, 39 inches diameter within the flywheel, 34 inches in the bearings, and weighs 75 tons without the centre. The construction of the flywheel is novel; the segments and arms are of cast steel and the centre of wrought iron. There are five centre rim segments, each cast in one piece, with two of the arms; this effectually prevents any two joints coming diametrically opposite to one another. On either side of the centre segments are disposed five plates linked together, and so arranged as to break joints with the centre segments to which they are riveted. This form of construction practically results in three flywheels, each self-supporting as to centrifugal force.

The most novel feature of this engine is the safety-stop arrangement, which consists of a small weight pivoted in the crank cheek and held in position by a spring. When the speed exceeds a certain limit the weight flies out, overcomes the action of the spring, and hits a small lever. This lever works a three-way cock that admits steam to a cylinder controlling a valve in the main steam-pipe. When steam is admitted to this cylinder it closes the valve, shuts off the steam, and so stops the engine. Steam can also be admitted by hand to this cylinder from the engine platform, thus stopping the engine. Forced lubrication is used throughout the engine.

L. S. R.

Brake Electromagnets for Electric Cranes. M. Vogelsang.

(Elektrotechn. Zeitschr., vol. xxii., 21 February, 1901, pp. 175–177.)

An illustrated description of a shunt-wound, iron-clad, brake-releasing magnet, provided with an automatic switch by means of which the resistance in series with the magnet-winding is short-circuited when the magnet is not excited. Hence, on closing the circuit, a very large current passes through the magnet coil, enabling it to exert a strong pull on the plunger, in spite of the long air-gap. The plunger, in rising, opens the short-circuiting switch, introducing the resistance into the short circuit, and reducing the exciting current to a safe limit for continuous working. A. H.

Novel Transmission and Control Gearing.

(Horseless Age, vol. viii., 10 April, 1901, pp. 29–30.)

This article describes a new form of gearing for motor vehicles, the distinguishing feature of which lies in the fact that, in the variable speed portion of the mechanism, the power is transmitted partly by belt and partly by chain. In the vehicle illustrated the double cylinder horizontal engine is placed at the front of a rectangular tubular under-frame, the crank-shaft being parallel to the length of the frame. A sprocket pinion at the back end of the crank-shaft drives by a single chain two sprocket wheels mounted on two counter-shafts parallel to the engine crank-shaft, and lying in the same horizontal plane. One of the sprocket wheels is fixed to its shaft, while the other, which is attached to an internal toothed drum, runs free. On the shaft having the fixed sprocket is keyed a stepped cone pulley, and on that carrying the loose sprocket is a similar stepped pulley running loose on the shaft. An open belt controlled by a striker transmits part of the engine power from the fixed to the loose pulley; a part is also transmitted by the chain drive to the loose sprocket wheel. The power is delivered to the shaft carrying the loose sprocket and pulley through the internal toothed drum of the sprocket wheel, and through satellite pinions running on spindles fixed to the loose belt pulley, which engage with the internal toothed drum, and with a spur wheel keyed to the shaft carrying the loose drum and sprocket. The power is thus divided up between the belt and chain in a proportion which depends on the rate of rotation of the satellite pinions relative to the internal toothed drum. The whole power is transmitted through the fixed spur-wheel and its shaft, and hence through a bevel gear to the differential cross-shaft, and finally, by independent chain drive to the road-wheels. The gear as illustrated gives four forward and two reverse speeds.

C. R. D'E.

Iron and Steel from the Standpoint of the Phase-Rule.

H. Le Chatelier.

(Metallographist, vol. iv., April, 1901, pp. 161–170; from the Bulletin de la Société d'Encouragement, 30 November, 1900.)

No less than eleven different phases are possible in a mixture of iron and carbon, but by the phase-rule it is shown that, neglecting the gaseous phase, (1) four phases can never exist together in equilibrium, and if four phases are detected the system is still undergoing change; (2) three phases can exist together only at a definite temperature and with a definite composition of each of the three phases, the relative proportions of which may alone vary; (3) two phases can exist together at any temperature, but the composition of these phases is dependent on the temperature, and can only be made to vary by changing the temperature; (4) one phase may exist at any temperature, and the composition of the phase can also be varied arbitrarily. By these rules the determination of the equilibrium between the eleven possible phases is greatly simplified, and becomes a practical problem.

It is shown that the curve representing the melting-point of mixtures of iron and carbon shows a slight break at 2·25 per cent. of carbon and a temperature of 1,275°; if this can be clearly established it is of considerable importance as showing that two different solid phases separate from the liquid at different temperatures, and these would probably be identical with austenite and martensite; this is thought to be more probable than Osmond's suggestion that martensite is a partially changed austenite.

When steel containing 0·9 per cent. of carbon is heated to the recalescence-point a double change occurs, which is made manifest by a sudden contraction in volume followed by an equal expansion. When quenched at the beginning of the contraction the steel was found to consist entirely of pearlite (a eutectic mixture of ferrite and cementite representing the stable equilibrium at ordinary temperatures); quenched at the maximum contraction it consisted almost entirely of troostite with a little pearlite and martensite; quenched at the end of the expansion it consisted entirely of martensite. This shows that the change is probably that represented by the scheme:—pearlite → troostite → martensite, and suggests that troostite is a modification which is stable within a very narrow range of temperature near the recalescence-point.

T. M. L.

Electrometallurgy of Copper. G. Codara.

(Elettricità, Milan, vol. xx., 12 January, pp. 20–21; 19 January, pp. 39–41; 26 January, pp. 56–57; and 2 February, pp. 67–70, 1901.)

The electrolytic separation of copper has one of two objects in view, either the separation of copper from its ores or its

purification. Various processes for the latter purpose are now in commercial use, and are gradually taking the place of non-electrolytic methods. The electrolytic separation of copper from its ores, however, has not yet succeeded industrially. Four processes have been tried—Body's, Siemens and Halske's, Höpfner's, and Marchese's. The first process employs a horizontal carbon anode on which the ore lies, the kathodes being copper plates enclosed in felt; the electrolyte, of ferric sulphate and salt, is kept in circulation. In Siemens and Halske's process the ore is first roasted to reduce the copper to subsulphide; it is then treated with a solution of ferric sulphate with free sulphuric acid, whereby copper sulphate is formed, which is then electrolysed. This process has been worked on a large scale at Martinikenfel, at Pena de Herro and in the Tyrol without success. In Höpfner's process the carbon anode and copper kathode are separated by a diaphragm, and separate currents of a solution of protochloride of copper in brine are passed over each. The solution passing the kathode deposits its copper, that passing the anode retains it in the form of bichloride; the two solutions combined are passed over the ore, which changes the bichloride again into protochloride, with liberation of sulphur. The process was tried in the Saxony Erzgebirge, at Giessen and at Wiedenau without success. At Safenburg it gave good results with Rio Tinto 3·37 per cent. ore, the production being 54 kilos of copper per HP. in twenty-four hours. In Marchese's process the low electromotive force required to decompose the sulphide was taken advantage of by having anodes of copper sulphide cast in the form of plates. The electrolyte of copper sulphate was obtained by treating rich ore with dilute sulphuric acid. The process was tried at Casarza and at Stolberg without success, the low electromotive force expected not being realised in practice. The last article is a description of the commercial process of purifying copper by electrolysis. The Author treats of the various impurities which may occur in the copper, their behaviour during electrolysis, their effect in impoverishing the electrolyte, and their effect on the back electromotive force. He then describes the various processes and vats of Siemens and Halske, Borchers and Goslar, Stahlmann, Hayden, Smith, Randolf, and Thofehrn. Copper electrolysis has its greatest development in the United States, where there are twelve plants with a total capacity of 400 tons daily. G. H. B.

Manchester Electricity Works.

(Electrician, vol. xlvi., 12 April, 1901, pp. 926–932.)

This article gives an account of the changes which are in progress at Manchester. A large power station is being erected at Bloom Street, which is to have a capacity of 14,000 I.HP. This is close to the Dickinson Street station, which has a capacity of

12,000 I.HP. A third generating station is to be erected at Stuart Street, having eventually 50,000 I.HP. installed. Continuous current is to be supplied to the consumer throughout; in the central area there will be a five-wire system, and in the outer area a three-wire system; in both cases the pressure between the outers will be 400 volts. At Stuart Street three-phase current will be generated at 6,500 volts, and be transmitted to a large number of substations, about a mile apart, where, by means of static transformers and rotary converters, it will be distributed as continuous current. A heavy demand is anticipated from the tramways, and as the result of spacing the substations at short intervals it is hoped that the maximum drop in the rails will be kept below 1½ volt. At Bloom Street the engine-room will contain four steam dynamos, running at 75 revolutions per minute, and giving about 1,900 kilowatts, either at 440 volts as shunt machines, or at 500 volts as compound-wound machines, the higher voltage being intended for the trams. The boiler-house will contain eleven Babcock boilers, each fitted with a superheater, and having a heating surface of 5,140 square feet. The economizers are to be fitted above the boilers, each boiler having its own economizer. The main flues will therefore discharge into the chimney at a level of 30 feet above the ground. The chimney is octagonal, 230 feet high and 12 feet across the octagon inside. This station is not yet complete, though it had been expected that it would have been in working order before last winter. No work appears as yet to have been done on the Stuart Street station, but mains have already been laid throughout the district. There will be thirty cables leaving this station, owing to the requirements of the Board of Trade that no cable shall carry more than 1,000 kilowatts. All three-phase feeders are of the same size, and are made up of three conductors, each 0·15 square inch in sectional area; they are lead-covered and armoured, and are laid in cast-iron troughing on the solid system. The troughs are 9 feet in length, and contain either two or three cables. One of the bridges in every length of troughing is of malleable iron, and is secured by set screws to the troughing; an iron clamp is then placed over the cable, and connected to the bridge so as to secure contact between the armouring and the length of troughing. In this way the troughing is made electrically continuous. The joint boxes are of special design, of which drawings are given. The mains were tested with a pressure of 13,000 volts between each conductor and earth, the other conductors and the armouring being connected to earth during the test.

A certain number of 100-kilowatt rotary converters have already been installed and put to work, though the method of working is intended as a purely temporary expedient. The system adopted is, however, interesting, as also is the method of testing. Continuous current at 440 volts is supplied to the rotaries, and by them converted to three-phase current at about 260 volts. This pressure is raised by static transformers to 5,000 volts, and the

power is then transmitted to a distant substation, where, by an inversion of the preceding process, it is reconverted to continuous current. At the substations the step-down static transformers have connections made to ten different points on the low-pressure winding, and these connections are brought out to terminals. By this means the regulation of the three-wire network is done without the aid of any balancers, the static transformers having their windings connected in a star, the common junction being connected to the middle wire of the distributing system. The rotary therefore supplies current direct across the outers. The testing was carried out as follows. Continuous current was supplied to a rotary converter, and by it converted to three-phase current; this was stepped up by one transformer and down by another, and then passed through a second rotary, the continuous current given out being absorbed by a resistance. Under these conditions the efficiency was determined by comparing the inputs and outputs on the continuous current sides, and in some cases this efficiency turned out as high as 81 per cent. at full load. Very similar results were given by a modification of the Hopkinson test, the continuous current from the second rotary being returned to the first. Figures are given showing the efficiency of the combinations at various loads.

The article contains drawings showing the connections on the switchboard for the three-phase transforming plant, the design of a disconnecting box for three-phase cables, the arrangements in the boiler-house to allow for expansion in the steam-pipes, and also a plan of the district to be dealt with by the various substations.

W. H. S.

Northwich Electricity Works.

(Electrical Review, vol. xlviii., 1 February, 1901, pp. 179–201.)

This station is worked on the direct current system, and is interesting on account of the fact that the Mond producer gas is used to provide the motive power. The works are situated on a piece of ground belonging to Brunner, Mond & Co., about 1,000 yards from the centre of the town. This site was chosen in view of the fact that the local gas company have a monopoly of the right to supply gas in the town, and it was thought that by placing the works on the site chosen, litigation might be avoided. Mond producer gas is supplied by Brunner Mond to the electric light company through a 12-inch cast-iron pipe, which leads to a gas-holder of 2,000 cubic feet capacity. The price charged for the gas is 2*d.* per 1,000 cubic feet. The Mond Gas is said to be remarkably clean; the sawdust scrubber requires cleansing only once a year, and it is said that although engines have been running as long as three years, not one of the pistons has ever been taken out of the cylinder. The main gas-engines are by Crossley, running

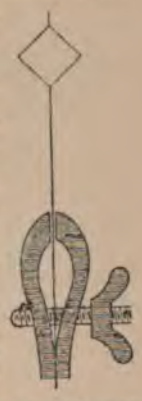
at 210 revolutions per minute; the flywheels weigh eight tons, and are of 8 feet in diameter. The larger dynamos are 60-kilowatt capacity, by Laurence, Scott, & Co., and give 125 amperes at 480 volts, being driven by belting at 600 revolutions per minute. There is also a set of chloride cells, 256 in all, having a discharge capacity of 200 ampere-hours. Much trouble has been experienced in connection with the distributing system owing to the frequent subsidences caused by brine pumping. In one case a large joint box completely disappeared, and the hole down which it disappeared was afterwards filled up with 600 tons of cinders. The method found most effectual in dealing with these subsidences is to roughly build a second chamber outside each brick junction-box chamber, and to leave a double bend of slack cable in it. Nearly all the consumers are on the further side of the Weaver River, which is crossed by a syphon of 12-inch cast-iron pipes, the joints being made with rubber rings between the flanges. The swing bridges over the Weaver, which have been already described, are supplied with power by the electric light company. The whole cost of energy for opening and closing the bridge only amounts to 0·83*d.* at 4*d.* per unit. The bridge was opened and closed 3,002 times during last year, the total cost of power required being £10 5*s.* 8*d.*

W. H. S.

Frequency of Alternating Currents. R. Wachsmuth.

(Ann. d. Physik, vol. iv., pt. ii., February, 1901, pp. 323–326.)

This is a description of an exceedingly simple method of determining the frequency of an alternate current, being superior as regards simplicity even to that of Samojloff.



It consists of a piece of watch-spring (see diagram) clamped in a vice, and provided with a small square piece of white paper stuck on by means of a bit of wax. When this is illuminated by a source fed by an alternating current and set vibrating, it will appear to stand still when the frequency of the current equals its own frequency of oscillation. The latter can be calculated from the formula, $N = \frac{7{,}920 \text{ thickness in millimetres}}{(\text{length in centimetres}^2)}$, but in practice a graduation could be easily marked on the spring itself. A small correction must be added for the paper in the case of light springs. The method is very convenient, and can be used for frequencies up to 150 per second, beyond which the springs become too stiff.

E. E. F.

Transparency of Röntgen Rays. L. Benoist.

(Comptes Rendus, vol. cxxxii., 11 February, 1901, pp. 324–327.)

Having shown that the absorbing power or specific opacity of a body increases with the density and that all bodies exercise a selective absorption on Röntgen radiation, the Author extends his researches to 120 bodies tested under the most varied conditions. Taking for his standard the absorption exercised by a block of paraffin 75 millimetres thick, and calling the equivalent transparency of a body the mass, in decigrams, of a prism 1 square centimetre base, which produces the same absorption as his standard, it is found:—(1) The specific opacity of a body is independent of its physical state, *e.g.*, it is the same for water as for ice. (2) The opacity is independent of the mode of atomic grouping, *e.g.*, of crystalline form, allotropic state, &c. (3) It is independent of the state of liberty or combination of the atoms; thus the equivalent transparency of a combination can, with certain limitations, be calculated from the transparencies of its constituent elements. It is found, plotting atomic weights as abscissas and the equivalent transparencies as ordinates, that these points lie on a regular hyperbolic curve. If, however, the character of the radiation is altered, either by altering the tube or interposing an absorbent screen, the same hyperbola is not obtained; from a study of these curves the fourth result is obtained, viz.: (4) The specific opacity of simple bodies, measured under well-defined conditions, is a definite function of their atomic weight and increases with the latter, the proportionality being nearly direct for rays of the most penetrating kind.

R. S. W.

Duration of Emission of Röntgen Rays. B. Brunhes.

(Soc. Franç. Phys., Bull., vol. clxiii., 1901, pp. 1–3. Discussion, pp. 3–4.)

The Author refers to his experiments already published, and describes further experiments. He finds that the emission of Röntgen rays lasts for a finite time, the duration being of the order of $\frac{1}{10000}$ to $\frac{1}{12000}$ of a second. In one experiment he connects a spark-gap and the Crookes tube in series with the secondary of an induction coil, and finds that while the spark always gives on a screen as clear and distinct images of a hole in a disk revolving rapidly as when the disk is at rest, thus showing it to be instantaneous, the Crookes tube, on the other hand, gives throughout a single image of the fluorescent screen. He accounts for the phenomenon by saying that the exact instant at which the spark passes is that at which the gaseous molecules strike the *kathode* in the Crookes tube. It is only afterwards that these *molecules* are repelled by the kathode, and this flux of kathode

rays, spreading out and creeping to the anti-kathode, strikes it during a finite time.

In the discussion P. Villard said the experiments described confirmed his own experiments on the duration of the emission of kathode rays, if it were supposed that the transformation of these rays into Röntgen rays were instantaneous at the moment of striking. Thus the duration of emission of the Röntgen rays would be really that of the kathodic emission. Colardeau described experiments he had made but not yet published, to show that the effects vary greatly according to the arrangement of the discharge circuit of the coil. If the Crookes tube is connected up directly to the terminals of the secondary it is traversed by several consecutive discharges even with a single interruption of the primary circuit. This was shown by directing the Röntgen rays on to a photo graphic plate revolving rapidly round an axis perpendicular to its plane, and interposing between the tube and the plate a piece of metal with a straight slot cut in it. Instead of a single image, a series of images was obtained, somewhat resembling the solar spectrum spread round the sector of a circle. But if a spark-gap is introduced into the circuit and the poles of the secondary shunted by a condenser of sufficient capacity to make the whole discharge take place in a single passage through the tube, the photographic plate shows only a single image of the slot, and this image is as clear as that given when the plate is at rest. A duration of about $\frac{1}{50000}$ of a second would have given a very noticeable enlargement of this image, and the speaker therefore concluded that the true duration of emission of Röntgen rays by a single discharge would be under this limit. In his reply to the discussion B. Brunhes maintained that in the conditions under which he had worked there was a clear difference of speed between the emission of the Röntgen rays and the spark in series with the Crookes tube, the former lasting $\frac{1}{100000}$ of a second while the spark was instantaneous. His photo left no doubt on this point.

W. C. H.

Explosion of Mines by Wireless Telegraphy. A. Breydel.

(Soc. Belge. Élect., Bull., vol. xviii., January, 1901, pp. 13–15.)

An arrangement of the usual form is described, the only peculiarity being that the whole is enclosed in a metal box, having only a small opening at one side to admit the rays from the transmitter. No vertical wire or collector of any kind is used, hence the apparatus is probably very insensitive. The Author remarks that tubes containing rarefied gases are more sensitive than metallic coherers to electrical radiations, and may be used with advantage.

J. E.-M.

Testing Magnet-Steel. I. Klemenčič.

(Ann. d. Physik, vol. iv., pt. 2, February, 1901, pp. 316–322.)

The usual method is somewhat rough and ready; it consists in magnetising, exposing to repeated shocks, and finding the amount of decrease in the magnetic moment. This may serve in cases where the magnet is intended to undergo vibration; but where the desideratum is a constant moment in a state of rest the principal cause of changes in the moment is variations in the temperature, and testing the steel for this involves extending the tests over a long time. The kind of steel which is best for the one purpose is by no means necessarily so for the other. Experimental data are given. In general, at rest magnets with smaller coercitive forces give better results, so that soft iron makes the most constant permanent magnet, its residual magnetism being astonishingly constant so long as no shock or vibration occurs.

A. D.

Accumulator Acid. R. Heinz.

(Centralblatt für Accumulatoren, vol. ii., 1 February, 1901, pp. 35–36.)

Sulphuric acid for storage cells must be very pure. It should be quite free from the metals that are precipitated by sulphuretted hydrogen, especially lead. The amount of iron should not exceed 0·01 per cent., nor that of chlorine 0·002 per cent., and of nitrogen, in whatever combination, the quantity should not be greater than 0·1 per cent. It should not have any organic impurities, and should be free from sulphuretted hydrogen. The Author has had a long experience of the manufacture of sulphuric acid, and especially of acids used in accumulators, and finds that much impure acid is in use. Brimstone acid is usually free from arsenic, but sometimes traces are found. Acid made from sulphur obtained as a bye-product from sulphuretted hydrogen can be depended upon as arsenic free. Such acids when concentrated in the usual platinum or platinum gold apparatus are as a rule very pure, and contain only traces of metallic impurities, and when diluted with pure water are very suitable for accumulator use.

W. W. H. G.

Electrolytic Phosphorus.

(Elect. World and Engineer, vol. xxxvii., 2 March, 1901, pp. 360–361.)

This article contains a brief illustrated description of the method of producing phosphorus, worked out by Dr. Machalske in his laboratory at Long Island City, New York. Ordinary

phosphate rock is used as raw material. No details are given of any preliminary grinding or mixing, so presumably the rock is used in its natural state.

The furnace is constructed of red brick and fire-clay. The sides are lined with calcined magnesia. The hearth is formed of a block of carbon, and forms one electrode, while a movable rod of carbon, 8 feet long and 4 inches in diameter, functions as the other. The actual furnace cavity is only 12 inches by 18 inches. Each furnace is provided with a hopper for charging the raw material, and with flues for carrying away the vapours of the phosphorus produced. These are condensed under water. The other product of the electrolysis is a slag which flows away as produced from outlets in the side of the furnace. No detailed figures for the yield of this furnace are given, but it is stated that, using electric energy costing 3 cents per E.HP.-hour, yellow phosphorus can be produced at a cost of only 7 cents per lb.

A company called the Anglo-American Chemical Company has been formed to exploit this process upon an industrial scale.

J. B. C. K.

A New Photophone. E. Ruhmer.

(Elektrotechn. Zeitschr., vol. xxii., 28 February, 1901, pp. 196–198.)

Basing his experiments on the discoveries and inventions of Graham Bell, Simon, and Duddell, the Author describes an ingenious form of photophone, in which the transmitter is an electric arc, and the receiver a selenium cell in circuit with a local battery and recording apparatus. It is suggested that such an apparatus could with great ease be fitted on board ship for signalling purposes, the arc of a searchlight being used as transmitter. As the system is telephonic, the messages would only be received by the ship on which the ray of light was directed.

J. E.-M.

Absorption of Gas in a Crookes Tube. R. S. Willows.

(Philosophical Magazine, vol. i., April, 1901, pp. 503–517.)

The Author here describes experiments undertaken to investigate the rate of absorption of gas in a Crookes tube, and the influences exerted by the nature of the gas, the size, shape, and material of the electrodes and the composition of the glass. To give some idea of the magnitude of the effects one experiment may be instanced. With a volume of 108 cubic centimetres and a pressure of 1 millimetre, a current of $10{\cdot}8 \times 10^{-4}$ amperes passing for 30 minutes reduced the pressure nearly one-eleventh.

It appears from the experiments that most, if not all, of the gas absorbed is to be accounted for by a chemical combination with the glass; that if tubes are desired in which the pressure remains constant they should be made of Jena-glass in preference to lead-glass, and of lead-glass rather than soda-glass; and finally, that in the first two cases hydrogen is absorbed to a far less extent than air or nitrogen, the last two gases showing little difference.

J. B. H.

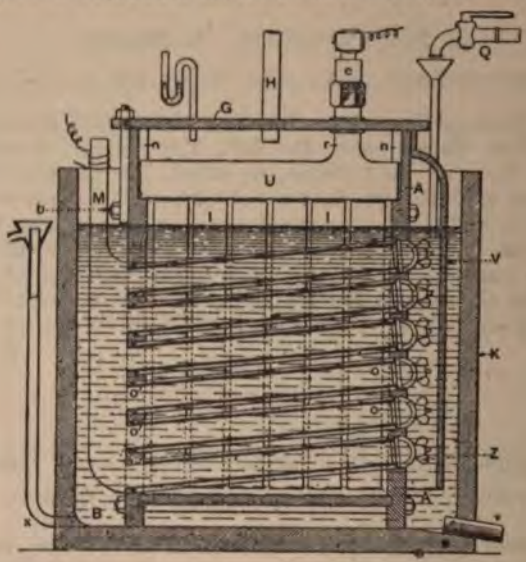
Outhenin-Chalandre Electrolytic Alkali Process.

J. B. C. KERSHAW.

(Electrician, vol. xlvi., 29 March, 1901, pp. 853–854.)

This process for the production of alkalies and chlorine compounds by the electrolysis of solutions of sodium or potassium chloride, is a diaphragm one, and is in actual operation at Chevres, near Geneva, and at Moutiers, in France, while works are being built for the same process in Italy and Spain.

The figure is a sectional elevation of the cell, which consists of



the outer and inner vessels, K and A. The inner vessel is filled with rows of porous-diaphragm tubes o o, in communication at one end with the chamber K, as shown. Each tube contains an iron kathode, which runs the whole length of its interior, while the anodes are round rods of carbon fixed into the lead head-piece *U*, from the surface of which the chlorine is carried away by the outlet pipe H.

The inner chamber A is nearly filled with a concentrated solution of sodium chloride, and the outer with dilute sodium hydrate. The electrical connections are then made.

The chlorine gas evolved is employed for the manufacture of bleaching powder, and for the manufacture of pure chemicals for laboratory and medical purposes, while liquefied chlorine is also one of the products of the works. The sodium liberated at the kathode surfaces decomposes the water, with formation of caustic soda, which, owing to its high specific gravity, travels down the tubes, and collects on the bottom of the cell, and when required is run off by the outlet pipe V.

The hydrogen liberated at the kathodes is collected and burned in a special form of burner in an atmosphere of chlorine, the resultant hydrochloric acid being fed into the anode chamber for the decomposition of hypochlorites. The excess of hydrochloric acid is split up by the electrolysis into its component parts, with production of chlorine at the anode and hydrogen at the kathode.

The advantages claimed for this class of cells are:—Complete separation of the electrolyte in the anodic and kathodic compartments, with consequent prevention of hypochlorite and chlorate formation. Collection and utilisation of the hydrogen evolved.

The Author is rather doubtful about the advantages of this cell, and until figures have been published, showing the yield under actual working conditions, comparison of its efficiency with the Castner and Hargreaves-Bird cells is impossible.

Photographs of the power station of the Geneva Municipality and the Electrolytic Alkali Works at Chevres, Switzerland, are also given. O. J. S.

Liquefaction of Hydrogen. M. W. Travers.

(Physical Society, vol. xvii., July, 1901. Proceedings, pp. 561–575; Discussion pp. 575–576; and Philosophical Magazine, vol. i., April, 1901, pp. 411–423.)

An account of the method whereby the Author has succeeded in obtaining liquid hydrogen in quantity. The apparatus consists essentially of a modified Hampson air-liquefier. The hydrogen, at a pressure of 200 atmospheres, undergoes a preliminary cooling to $-80°$ C. in solid carbonic acid and alcohol. It is then successively cooled by liquid air boiling under atmospheric pressure, and under a pressure of 100 millimetres, after which it escapes from the Hampson valve, and being a sufficiently imperfect gas at the low temperature ($-200°$ C.) obtained by the liquid air boiling under low pressure, regenerative cooling is produced, as in the liquefaction of air by the Hampson machine, and liquid hydrogen is obtained. It is collected in a vacuum vessel which is specially insulated from external heat. For further details reference must be made to the original paper, which is illustrated by a plate.

F. G. D.

Vitrified Quartz. W. A. Shenstone.

(Nature, vol. lxiv., 16 May, 1901, pp. 65–67. Paper read before the Royal Institution, 8 March.)

The Author describes his method of making tubes of this material, pointing out the difficulties to be overcome. When once prepared, these tubes are for many purposes much superior to glass tubes, as, for example, for use in thermometry. The mean coefficient of expansion of a rod of vitrified silica is only 0·00000059; its expansion is exceedingly regular up to 1,000°, and if not heated beyond this temperature it returns very exactly to its original length when cold. Above 1,000° the rate of expansion diminishes rapidly, changing to a contraction at about 1,200°. Experiments on the transparency of this substance to ultra-violet rays show that tubes made of it are much more suitable than glass ones for use in studying the spectra of electric discharges. Its most remarkable property is its behaviour under sudden changes of temperature. When white hot it may be plunged into cold water, or even into liquid air, without injury. For use in thermometers, and for researches on pure gases and on the behaviour of gases at high temperatures, it should prove much superior to glass. It has some defects, however, as it is slightly permeable to hydrogen at about 1,000°, and it is attacked, when hot, by alkaline oxides.

W. C. H.

Rubber Tires. Michelin.

(Horseless Age, vol. vii., 2 January, 1901, pp. 21–26. Paper read before the International Automobile Congress.)

There are four classes of tires: (1) Solid tires put on the rims by force, (2) cemented, (3) wired, and (4) fastened by bolts. Pneumatic tires deal with obstacles up to 1¼ inches; springs up to 4 inches. On motor cars pneumatics are chiefly valuable in preserving the life of the machinery. A steel wheel rolling on steel ground would have its speed increased if provided with a pneumatic tyre; but the Author deprecates making any formulas about roads, and relies entirely upon trials. He has found a solid rubber tire better than iron on wood or snow-covered ground, but inferior when the road is hard and smooth. An electric cab was run 2 kilometres on solids at an average speed of 13·94 feet per second, and the energy taken was 1,037,680 watt-seconds. The same cab, with four pneumatics, made the same distance in the same day with 817,840 watt-seconds (diameter of wheels not given). Another experiment was made with 17·9 per cent. energy economy, and 5·3 per cent. gain in speed. The starting pull on a *dead* level was found to be 14 per cent. lower with pneumatics, the trial being effected by weights added to a pan connected to the

car through a pulley. Mauny states that in transporting 1 ton of useful load a wear of 4 grams of iron per kilometre was lost. The wear of a pneumatic tire depends on small factors, for example, on steering-wheels; the play of a bad steering-gear increases the wear appreciably, as does also the slip of the tires when the brakes are applied. The effect of dishing the wheels on the wear is remarked upon. The dishing of the front and rear wheels on the Darracq is 6 per cent. and 3 per cent. respectively, Peugot 2 per cent. and 4·7 per cent., Dietrich 3 per cent. and 6 per cent., and on the Panhard 4 per cent. Armoured tires and self-healing tires do not seem to be practicable.

M. O'G.

Explosive Power of Acetylene. R. H. Fenn.

(Engineering News, vol. xliv., 1900, pp. 366–367. Condensed from a graduating thesis presented at the Clarkson School of Technology, Potsdam, New York.)

Photographic views are given of the cylinder and apparatus for testing the pressure of explosive mixtures of gas and air, including a gauge reading to 100 lbs. per square inch for initial pressure, an induction coil and sparking device to explode the mixtures, and a Crosby indicator using a 300-lb. spring with barrel belted to a revolving shaft giving a card with a continuous line for the rise and drop of pressure. A small generator produced the acetylene, each charge of which was measured over water in a calibrated bottle.

Experiments were made at initial atmospheric pressure with mixtures ranging from 15 parts by volume of air to 1 part of acetylene, to 3 parts air to 1 part acetylene. The 3:1 mixture showed very markedly the poor combustion due to lack of air, a heavy black soot being driven out of the cylinder on exhausting. A mixture of air to gas in the ratio of 9:1 gave the greatest explosive pressure, 112 lbs. per square inch. This was increased to 350 lbs. when the initial pressure before ignition was increased to 35 lbs. per square inch.

For comparison, a series of tests were made with mixtures of air and vaporised gasoline in the ratio 4:1, which gave the greatest explosive pressure, 165 lbs., at initial pressure of 20 lbs. At the same initial pressure the 9:1 mixture of air and acetylene produced a pressure $\frac{273}{165}$ greater than that by the gasoline, so that the volume of acetylene to give the same pressure need only be $\frac{1}{2} \times \frac{165}{273} = 0{\cdot}304$ of the gasoline.

Taking the theoretical indicator diagrams for the explosion of these two mixtures, the area of the acetylene diagram measured *4·91 square inches*, and that of gasoline 1·79 square inches, giving

a ratio of power nearly 3 : 1. Indicator diagrams show that the time-rate of the acetylene explosion is five times faster than that of the mixture of gasoline and air. A large quantity of heat is absorbed by the iron walls about the gas, thus reducing the maximum pressure, which is a function of the heat evolved by the explosion. As vaporised gasoline acts more slowly than acetylene, the practical test makes acetylene (mixture 9 : 1) 3·28 times more powerful than gasoline (ratio of 4 : 1), whereas theoretically it should be only three times as great.

The calorific value of the acetylene used was 1,350 thermal units and that of gasoline 700 heat units per cubic foot. A cubic foot of each of the above mixtures at initial atmospheric pressure would give 90 lbs. and 43 lbs. per square inch respectively. Allowed to expand adiabatically to 10 cubic feet, the calculated external work—

$$W=\frac{p_1v_1}{K-1}\left\{1-\left(\frac{v_1}{v_2}\right)^{K-1}\right\}, \text{ (where } K = 1{\cdot}405),$$

would be for acetylene 22,403 foot-lbs., and for gasoline 12,132 foot-lbs. But only 0·0625 cubic foot of acetylene was used, while 0·20 cubic foot of gasoline was needed, or 3·2 times as much. With the given ratios of mixtures only 0·0312 cubic foot of acetylene is required to do the same work that 0·20 cubic foot of vaporised gasoline will do. Or comparing equal quantities of the two gases, acetylene has about 6·5 times the intrinsic energy of vaporised gasoline at the given ratios of air and gas.

Assuming an engine of total efficiency from fuel to useful work of 15 per cent., and a consumption of 22 cubic feet of gasoline gas per HP. per hour, the cost of 1 HP.-hour would be 0·65*d.* (1·3 cents), at 2*s.* 5*d.* (58 cents) per 1,000 cubic feet of vaporised gasoline. The cost per HP. per hour for acetylene in an engine of equal efficiency would be 1·3*d.* (2·6 cents), with acetylene 33*s.* 4*d.* (8 dollars) per 1,000 cubic feet. To do the same work with acetylene in place of vaporised gasoline, therefore, would be about twice as expensive. For this reason acetylene would only be of practical use to produce power where light compact engines were required, as in automobiles. In the event of a 50 per cent. reduction in the price of calcium carbide, however, it might probably come into more general use for gas-engines.

W. R.

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MINUTES OF PROCEEDINGS,

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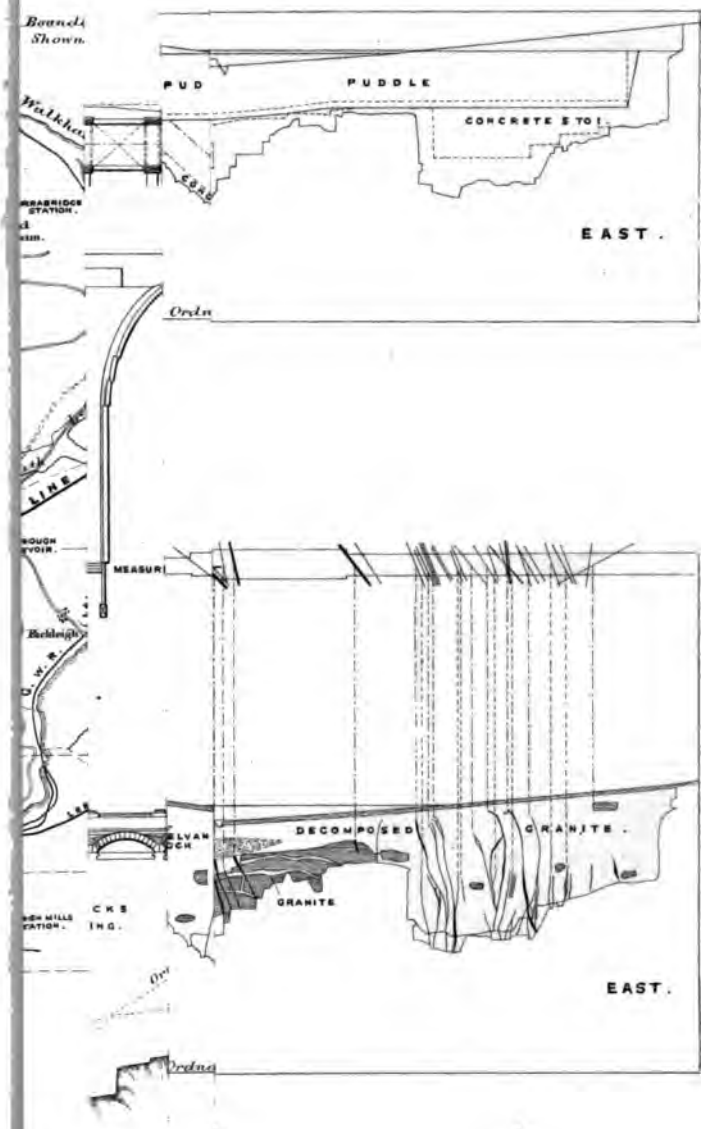
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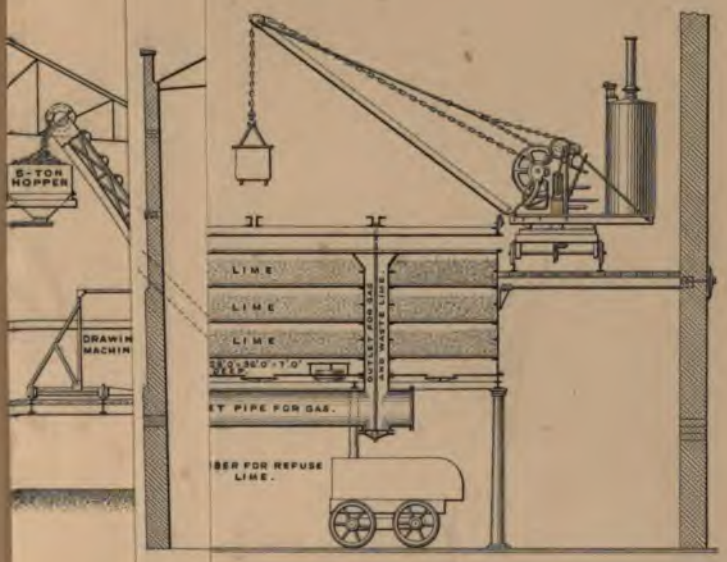


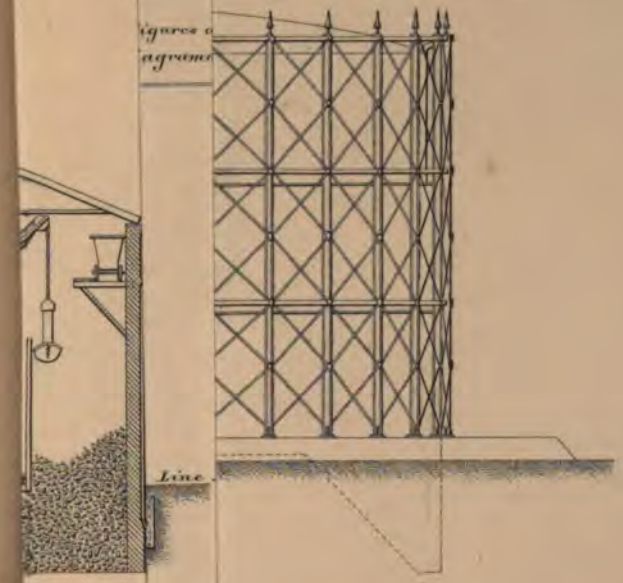





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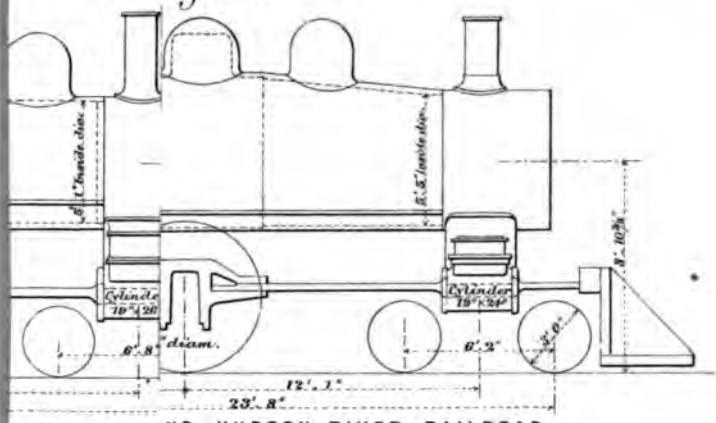
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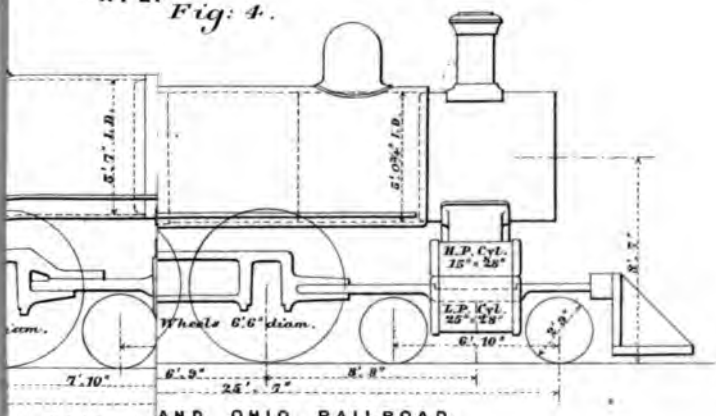
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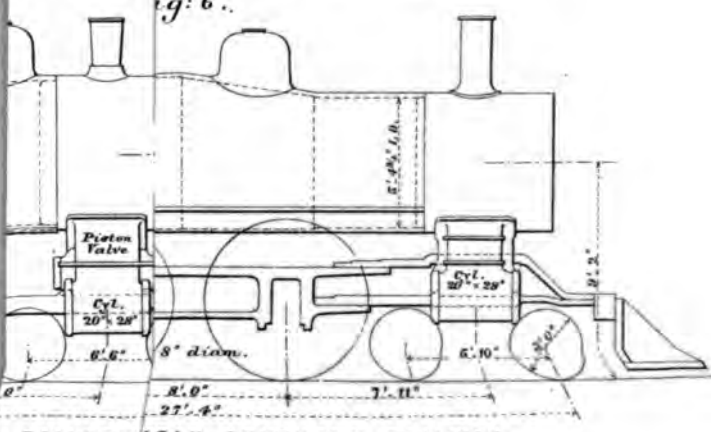
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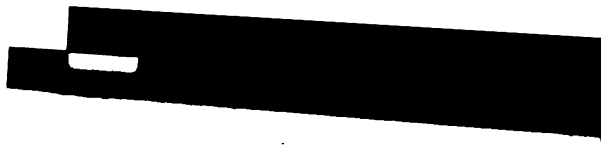
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